

# **Application of Naturalistic Decision Making Models to Support Command and Control Decision Making**

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# Presentation Overview



- Cognitive models of human decision making
  - “Naturalistic” vs. traditional model
- Complex tasks
- Situation awareness
- Approach to developing a Decision Support System
- Advantages of graphic presentations
- Describe DSS and expected payoffs

# **“Naturalistic” Decision Making**



- Dynamic, fluid situations
- Time pressure
- High risk
- Multiple players
- Shifting and competing goals
- Action-feedback loops
- Uncertain and incomplete data

# **“Naturalistic” Decision Making Models**



## **Decision strategies people use under real-world conditions**

- Experienced real-world decision makers rarely use traditional resource intensive strategies under dynamic, adverse conditions and time pressure.
- Recognize and appropriately classify situations
  - Once recognized, the response option follows
  - Use limited time to evaluate feasibility

## **Feature matching and recognition-primed decision model**

- Involves an organization of memory, or “schemas,” and information processing to assess situation and identify promising actions.
- Incoming information is categorized, selected, edited and organized on basis of person’s prior knowledge about a domain.
- Occurs when decision maker recognizes features of present situation as similar to a previous situation.



# **“Naturalistic” Decision Making**

Story generation and explanation-based reasoning model

- Occurs in complex situations where decision maker may not have all information or facts contradict each other.
- Construct a causal model to explain available evidence
- Employed when body of evidence is large, complex, and implications of its components are interdependent.

Both cognitive strategies are used where a large base of implication-rich, conditionally dependent pieces of evidence must be evaluated before selecting course of action.

- Feature Matching – spatio-temporal dependence.
- Story generation - causal dependence.

# **“Naturalistic” Decision Making Models**



Option generation and evaluation

Analysis of all available data and analysis of all possible hypotheses

- Specify all relevant features of the task
- Identify the full range of options
- Identify the key evaluation dimensions
- Rate each option of each dimension
- Tabulate the results
- Unrealistic for situations requiring rapid decision making

# Decision Cycle for Experienced Decision Makers



Experienced decision makers use knowledge to:

- Seek information
- Identify and interpret the problem
- Understand the significance
- Derive the intention
- Evaluate the choice
- Anticipate the consequences

# Task Complexity



At any point in time, the decision maker may be simultaneously:

- Monitoring the effect of an action against the first track,
- Selecting a countermeasure to use against a second track,
- Identifying a third,
- Detecting a fourth,
- Responding to requests for information from higher authority, all the while
- Synthesizing reports from various sensor operators in CIC,
- Prioritizing contacts and associated actions,
- Updating the status of critical tracks,
- Strategically managing workload of a multitask system under dynamically changing conditions.

# Situation Awareness



The ability to:

- Maintain an accurate perception of the surrounding environment
- Identify problems and/or potential problems
- Recognize a need for action
- Note deviations in the mission
- Maintain awareness of tasks performed

# Cognitive Challenge for Tactical Decision Maker



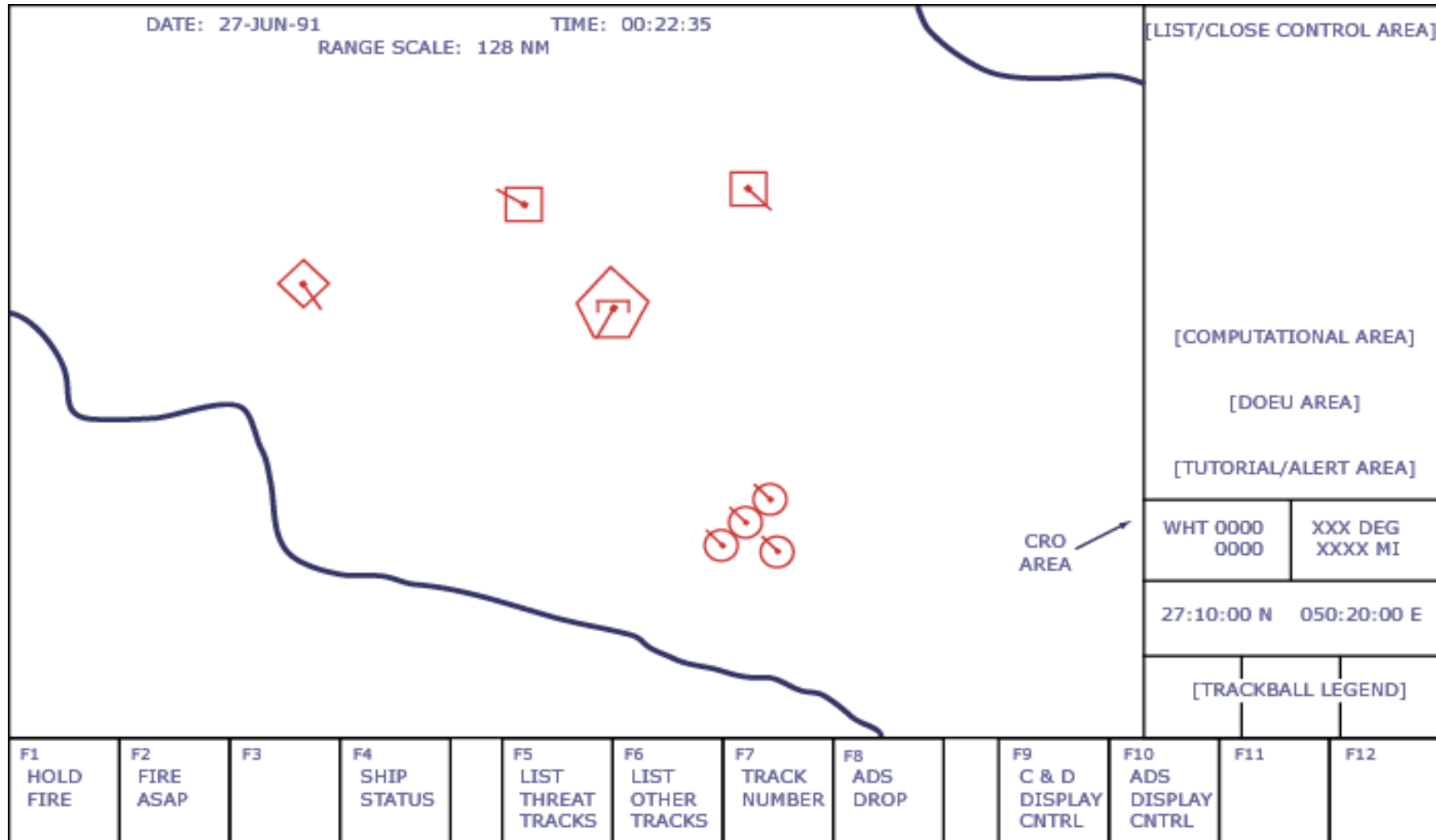
Making inferences from incomplete/uncertain data

- Derived from multiple sources,
- Relating to several concurrent threats,
- Under time-compressed conditions.

Cognitive functions are data and resource limited

- Mental resources of the decision maker
- Inability of sensors to provide complete, error-free, unambiguous data to support the identification process

# Aegis Display for CO and TAO



# Memory & Cognitive Processing Requirements Exceed Human Capacity



## Requisite AAW sub-tasks:

- Assess complex situations
- Resolve contradictions
- Adapt and correct hypotheses
- Determine priorities among subtasks
- Select & initiate action alternatives and assess their consequences
  - Correlate and keep track of goals & sub-goals
    - Maintain a queue of waiting subtasks
    - Handle interruptions
    - Manage the individual and collective loads of the tasks.



# Difficult Decisions in CIC (I)



WHAT IS THE DIFFICULT DECISION?	WHY IS IT DIFFICULT?	HOW IS THE DECISION MADE?
Track identification	Many pieces of data fit with multiple hypotheses	Often involves feature Matching to make initial assessment  Critical cues: IFF, speed, course, ESM, altitude
Recognizing a problem	Large number of tracks are monitored for changes in any of several key parameters	Must notice or be informed of change in track behavior

# Difficult Decisions in CIC (II)



WHAT IS THE DIFFICULT DECISION?	WHY IS IT DIFFICULT?	HOW IS THE DECISION MADE?
Determining intent	DMr relies on ambiguous data	Often involves story generation to assimilate cues  Critical cues include: course, range, and point of origin
Avoiding escalation	Requires memory of past as well as current events	Monitors changing risk associated with suspicious track

# TADMUS Experimental Procedure



- Focus on commanding officer and tactical action officer
  - 12 active duty Naval personnel
- Pre-experimental package sent two weeks prior to experiment
- Decision-making evaluation facility for tactical teams (DEFTT) laboratory
- Simulates computer consoles of Navy Aegis Cruiser combat information center
  - Six-station test-bed environment
  - Four AAW Support Team member roles are filled by confederates
  - Four experimental scenarios (25 minutes each)
- 11-18 contacts of interest/scenario

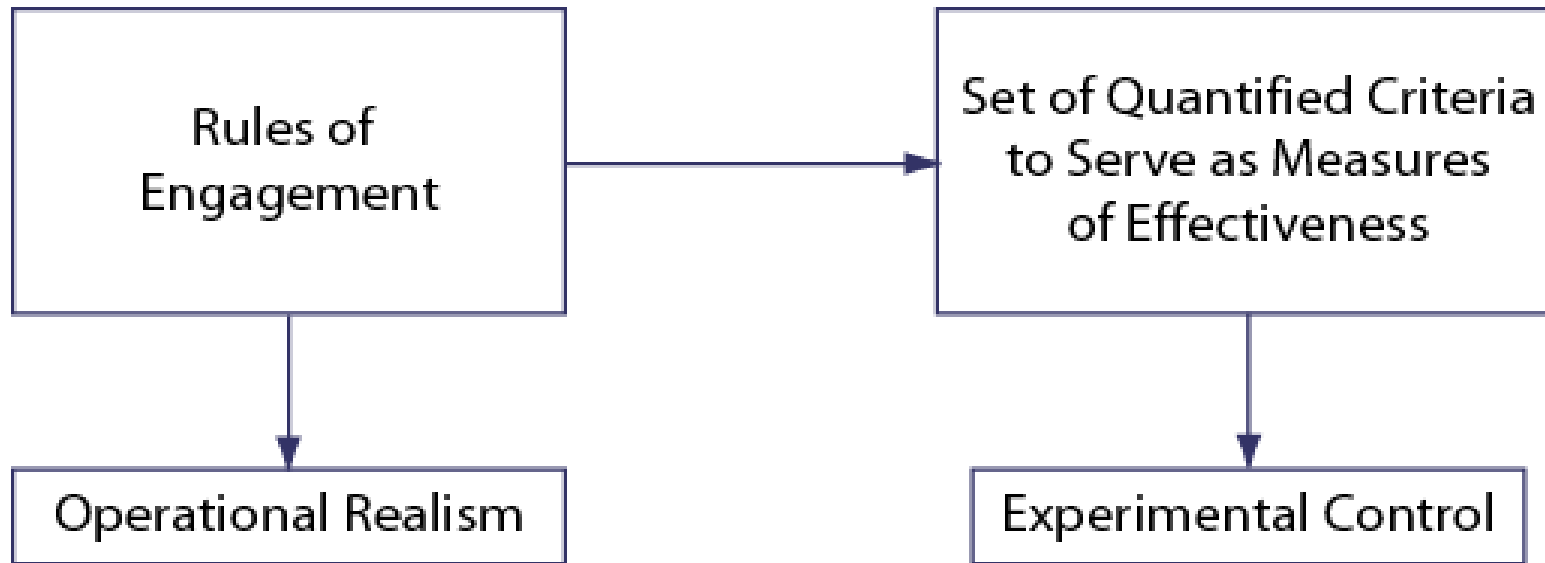
# Hot Wash Up Reports: Tally of Errors



## HOT WASH UP REPORTS: TALLY OF ERRORS

	SCENARIO					
ERROR TYPE	A	B	C	D	I	Total
Slow to detect and respond to COI	6	4	2	0	3	15
Comms w/in team not acted upon	7	5	1	3	5	21
Delay in taking COI under close control	3	3	2	2	2	12
Delay in issuing standard warnings	5	1	0	2	2	10
Premature issuing warnings	1	1	0	0	0	2
Failure to inform higher authority	7	1	1	1	1	11
Lost tactical picture	4	1	4	18	6	33
Failure to use reported sensor info	2	1	1	1	0	5
Failure to clear clutter	2	1	2	1	1	7
Failure to verify reported track	3	1	1	0	1	6
Failure to take appropriate response (ROE)	1	0	2	3	3	9
Failure to use EW softkill	3	1	2	3	2	11
Issue wrong warning level	1	1	0	0	0	2
Failure to ack./act upon Intell message	1	1	0	1	0	3
TOTALS	47	22	18	35	26	148

# Measures of Effectiveness



Establish Defensive Posture  
Issue Warnings  
Establish Friendly Force Criteria  
Respond to Changes in Kinematics and IFF  
Inform Battle Group Commander  
Illuminate with Fire Control Radar

# Error Analysis Vignette D: Run #7



TAO--GB: <sup>7</sup>

Contact Kuwait tower to see if 7010 correlates to com. Swiss Air.

GB--TAO: <sup>8</sup>

Roger Golf Bravo

Error!  
TAO does not contact Kuwait tower until reminded again later by Golf Bravo.

TIC Issues warning to track #7010: <sup>9</sup>

Unidentified aircraft course 345, 29 miles. Alter course to 040.

CO--TAO: <sup>10</sup>

He's at 405 knots, 20,000 feet, descending in altitude.

Error!  
TAO does not mention track number.

TAO--CO: <sup>11</sup>

OK

CO--TAO: <sup>12</sup>

He's way off the commercial airways.

Error!  
TAO does not mention track number.

# Relating Errors to the Difficult Decisions in CIC



DETERMINING INTENT	WHY DIFFICULT	DSS FIX
<p><b>TAO lost tactical picture, i.e., he failed to stop TIC from initiating Tornado procedures</b></p> <p>(an unnecessary and potentially provocative act) because he was unable to recall prior known information related to this track—that this track (7010) has a valid mode 3 IFF (corresponds to Comm air) and had been evaluated as probable Comm air earlier (box 3—right at beginning of scenario). [box 23]</p>	<p><b>Memory limitations.</b></p> <p>Task requires memory of past as well as current events.</p>	<p>Display of trend info.</p>

# Relating Errors to the Difficult Decisions in CIC



RECOGNIZING A PROBLEM	WHY DIFFICULT	DSS FIX
<p><b>Failure to take appropriate action(s).</b></p> <p>Contacts (7011 and 7012) are within 30nm ROE limit, yet no action has been taken. [This error also applies to Track Identification.] [box 28]</p>	<p><b>Limited resource capacity.</b></p> <p>A large number of tracks are monitored for changes in any of several key parameters.</p>	<p>Tripwires.</p>



# Baseline on Tactical Decision Making: Losses of Situation Awareness



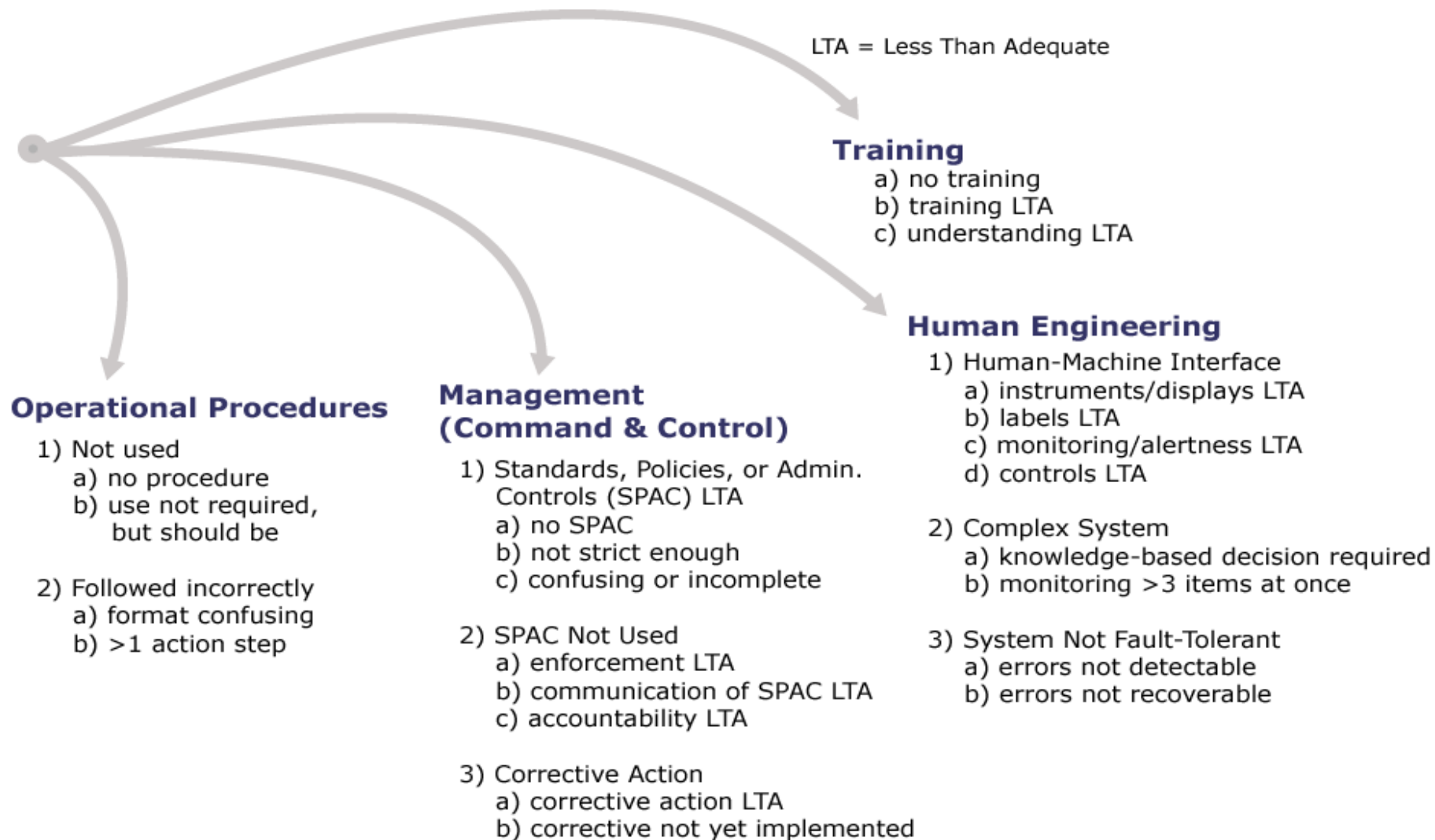
## Short-Term Memory Limitations:

- Mixing up and forgetting track numbers
- Confusing/forgetting kinematic data
- Associating past actions or events with the wrong track number or associating completed actions with the wrong track number

## Decision Biases:

- Carrying an initial threat assessment throughout scenario regardless of new information
- Assessing a track based on information other than that associated with the track (e.g., old intelligence data, assessments of similar tracks, outcomes of unrelated events, past experiences)

# TADMUS Root Cause Analysis Tree



# Excerpts from TADMUS Experiment

## Error Analysis: Scenario D, Run 11



**TIC--TAO:** 22  
TAO, TIC initiating tornado procedures to track number 7010.

**Significant Error:**  
Lost tactical picture. Track 7010 has valid mode 3 IFF. Tornado procedures are unnecessary and potentially provocative. (see block 3)

1. Does not provide bearing, range, speed, or altitude of track 7010.
2. Does not provide assumed identity of track 7010, e.g., unknown air, hostile surface, etc.

**TAO--TIC:** 23  
Roger, TIC.

**Significant Error:**  
Lost tactical picture. TAO does not stop TIC from initiating Tornado procedure on track 7010. (see blocks 3 and 22)

1. Does not inform GB or Rainbow that track 7010 is receiving warnings.
2. Does not identify himself as TAO.

**TAO--AAWC:** 26  
7010, 7012, same track?

1. Does not provide bearing, range, speed, or altitude of tracks being discussed.
2. Does not provide assumed identity of tracks being discussed.
3. Does not direct EW to perform track correlation of tracks being discussed.
4. Does not indicate who's speaking.
5. Does not identify himself as TAO.

**AAWC--TAO:** 27  
Stand by, sir, let me verify that with Rainbow.

1. Does not provide track numbers of tracks being discussed.
2. Does not indicate who he is speaking to.
3. Does not identify himself as AAWC.

**Significant Error:**  
Lack of resolution of confusion associated with 7010 and 7012 leads to later confusion and mismanagement of these tracks.

Never contacts Rainbow or resolves the confusion regarding 7010/7012.

**TIC--TAO:** 28  
7011 and 7012 are two of the same.

**Significant Error:**  
TIC assumes that 7011 & 7012 are the same track. Contacts are within 30nm ROE limit, yet no action has been taken.

1. Does not provide bearing, range, speed, or altitude of tracks being discussed.
2. Does not provide assumed identity of tracks being discussed.
3. Does not provide basis for this statement, e.g., visual ID, Rainbow, etc. (Does he mean that these two tracks are two of the same group, or that the two tracks are one in the same, meaning that they are the same track?)
4. Does not indicate to whom he is speaking.
5. Does not identify himself as TIC.

**IDS--TAO:** 29  
Also, 7007, right there, you've got 2, 3 tracks right in close there.

1. Does not provide bearing, range, speed, or altitude of track 7007.
2. Does not provide assumed identity of track 7007, e.g., unknown air, hostile surface, etc.
3. Does not request EW correlation of track 7007.
4. Does not indicate who he is speaking to.
5. Does not identify himself as IDS.

**IDS--AAWC:** 30  
AAWC, IDS, tracks 7011, 7007 they're both next to each other, I'm getting a garbled IFF response.

1. Does not provide bearing, range, speed, or altitude of tracks 7011 or 7007.
2. Does not provide assumed identity of tracks 7011 or 7007, e.g., unknown air, hostile surface, etc.
3. Does not request EW correlation of tracks 7011 or 7007.

# TADMUS Root Cause Analysis Tree



LTA = Less Than Adequate

## Training

- a) no training
- b) training LTA
- c) understanding LTA

## Human Engineering

- 1) Human-Machine Interface
  - a) instruments/displays LTA
  - b) labels LTA
  - c) monitoring/alertness LTA
  - d) controls LTA
- 2) Complex System
  - a) knowledge-based decision required
  - b) monitoring >3 items at once
- 3) System Not Fault-Tolerant
  - a) errors not detectable
  - b) errors not recoverable

## Management (Command & Control)

- 1) Standards, Policies, or Admin. Controls (SPAC) LTA
  - a) no SPAC
  - b) not strict enough
  - c) confusing or incomplete
- 2) SPAC Not Used
  - a) enforcement LTA
  - b) communication of SPAC LTA
  - c) accountability LTA
- 3) Corrective Action
  - a) corrective action LTA
  - b) corrective not yet implemented

## Operational Procedures

- 1) Not used
  - a) no procedure
  - b) use not required, but should be
- 2) Followed incorrectly
  - a) format confusing
  - b) >1 action step

# TADMUS Root Cause Analysis Tree



LTA = Less Than Adequate

**DEFTT Lab Equipment  
Reliability or Operation LTA**

## Human Cognitive Limitations

- 1) Info Acquisition/Memory
  - a) Conflicts among data modalities & types
  - b) Over-emphasize certain data (bias)
  - c) Selective perception based on false expectations
  - d) Ignore base-rate info (known info)
  - e) Improper interpretation of data based on context (framing)
  - f) Forgot/confused data (STM)
  - g) Incorrect recall (from LTM)
  - h) Failure to search for/monitor data
- 2) Info Processing/Limited Resource Capacity
  - a) Failure to include new data and/or weight data properly
  - b) Excessive data requirements (to ensure low uncertainty)
  - c) Failure to consider variability of data
  - d) Errors in adopting appropriate schema (representativeness, garden path, etc.)
  - e) Failure to prioritize goals/objectives
- 3) Workload
  - a) High degree of time pressure
  - b) Number of tracks/many actions required
  - c) High degree of mental effort
  - d) High degree of emotional stress
  - e) Frequent distractions/interruptions

## Immediate Supervision

- 1) Preparation
  - a) no preparation
  - b) pre-job briefing LTA
- 2) Supervision During Work
  - a) crew teamwork LTA

## Communications Procedures

- 1) Misunderstood Verbal Communications
  - a) standard terminology not used
  - b) repeat back not used
  - c) long message
- 2) Not Used
  - a) no procedure
  - b) use not required, but should be
- 3) Followed incorrectly
  - a) format confusing
  - b) >1 action step



# TADMUS Root Cause Analysis Tree



## Human Cognitive Limitations

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# Modifications Made to TapRoot System



- Techniques to display data, understand sequences of information flow, identify causes for errors
- TADMUS requires explanations based in cognitive psychology literature
- Modifications:
  - Streamline documentation phase
  - Impose more structured approach to analysis
  - Extend list of Root Causes

# Taproot Analysis Example



TIME	SPEAKER	COMMUNICATION/ TRIPWIRE EVENT	SIGNIFICANT ERRORS
0:09:24	AAWC speaking to TAO	TAO, AAWC, track 7014, I just talked to Broadsword about it, that's her helo, Broadswords helo	
0:09:32	CO speaking to AAWC	7014?	
0:09:33	AAWC speaking to CO	Yes sir.	
0:09:34	TAO speaking to AAWC	Aye	
0:09:41	GB speaking to GS	(Background comms.)	
0:09:42	TIC speaking to TAO	TAO, TIC, no response on level one from track 7024	
0:09:51	GS speaking to GB	(Background comms.)	
0:10:01	Co speaking to TAO	OK, the track 7021 is down at 18,000 feet.	
0:10:01	GB speaking to GS	(Background comm..)	
0:10:05	TAO speaking to Co	Yes sir.	
0:10:06	TAO speaking to CO	Sir, right now my contacts of interest are 7021 and 22, and two F-1s from Basrah. 7024 the P-3 is closing our position from the east and 7023 the helo to which we have issued level one, with a negative response. I am going to recommend level two.	At time 5:20 the TAO told the CO that one of his contacts of interest was 7005. 7005 has not yet been ID'd and he doesn't include it here as one of his current contacts of interest.
0:10:19	Co speaking to TAO	Level two to the helo. Have we done level one to the P-3?	
0:10:22	TAO speaking to CO	Negative sir.	
0:10:23	CO speaking to TAO	Let's do level one to the P-3.	
0:10:25	TIC speaking to CO, TAO	Yes, I've completed level one to the P-3 and I got no response.	
0:10:30	CO speaking to TIC	OK.	
0:10:31	TIC speaking to CO, TAO	So you want me to issue a level two to 7023	
0:10:34	TAO speaking to TIC	Yes, level two to 7023.	
0:10:37	CO speaking to TAO	And Air, TAO, cover 7023 and 24 with birds.	
0:10:37	Cp speaking to TAO	With birds, yep. And who's 7002?	



# Taproot Analysis Example



TIME	SPEAKER	COMMUNICATION/ TRIPWIRE EVENT	SIGNIFICANT ERRORS
0:10:39	TIC speaking to Puma 1	(Issues level two warning to aircraft on course 230, speed 80, altitude 1000. Alter course to 000.)	
0:03:21	Rainbow speaking to GW	Golf Whiskey, this is Rainbow, two new tracks, 7020, 7021, 321 Gold Whiskey, 100 nautical miles, course 110, speed 200 knots, out.	
0:03:21	TAO speaking to CO	Yes sir.	
0:03:23	TIC speaking to CO	Roger, sir.	
0:03:24	<b>Within Weapon Range</b>	Track 7023 (Puma) with Exocet range.	No Defensive Measures
0:03:25	EW speaking to TAO, AAWC	TAO and AA, this is EW, I have a Primus-40 bearing 048	
0:03:38	AAWC speaking to EW	Gulf Stream, ESM, this guy?	
0:03:43	EW speaking to AAWC	Could be either Gulf Stream of a Super Puma.	
0:03:45	TAO speaking to EW, AAWC	Right not, that's a 1000 feet at 80 knots. I would say that's track 7023 correlation.	
0:03:46	AAWC speaking to EW	OK.	
0:03:54	AAWC speaking to TAO	Yes.	
0:03:55	TAO speaking to All stations	So it looks like that's a helo	
0:03:57	TAO speaking to CO	Captain, I'd like to go with a level two on track number m7023 coming in from the ah, he's only 14 nautical miles away.	Warning inside Iranian territorial airspace.
0:04:03	CO speaking to TAO	Concur, concur, yeah go ahead.	
0:04:07	TAO speaking to IDS (TIC)	ID, go level two on track 7023, bearing 048, 14 nautical miles.	
0:04:13	TAO speaking to AAWC	And AAWC, TAO, let's illuminate track 7023.	
0:04:21	TIC speaking to TAO	This is TIC, understand level two, 7023.	
0:04:24	TAO speaking to TIC	That's affirm.	
0:04:25	TAO speaking to AAWC	AAWC, did you copy illuminate track 7023?	
0:04:25	TIC speaking to Puma 1	Unidentified aircraft, course 230, speed 80 knots, altitude 1000 feet, position 29 degrees, 11 minutes north, 050 degrees, 11 minutes east, this is US Navy warship. Your intentions are not clear. Request you identify yourself immediately alter course to 090 to remain clear of my position over.	
0:04:29	AAWC speaking to TAO	This is AAWC, affirmative, I copy sir.	

# Tactical Decision Making Under Stress Goal



Design a decision support system to:

- Minimize mismatches between cognitive characteristics of human decision-maker and decision tasks;
- Mitigate shortcomings of current systems that levy high cognitive workload and exceed human memory limitations; and
- Synthesize numeric data into graphic presentations to facilitate interpretation of spatial data.

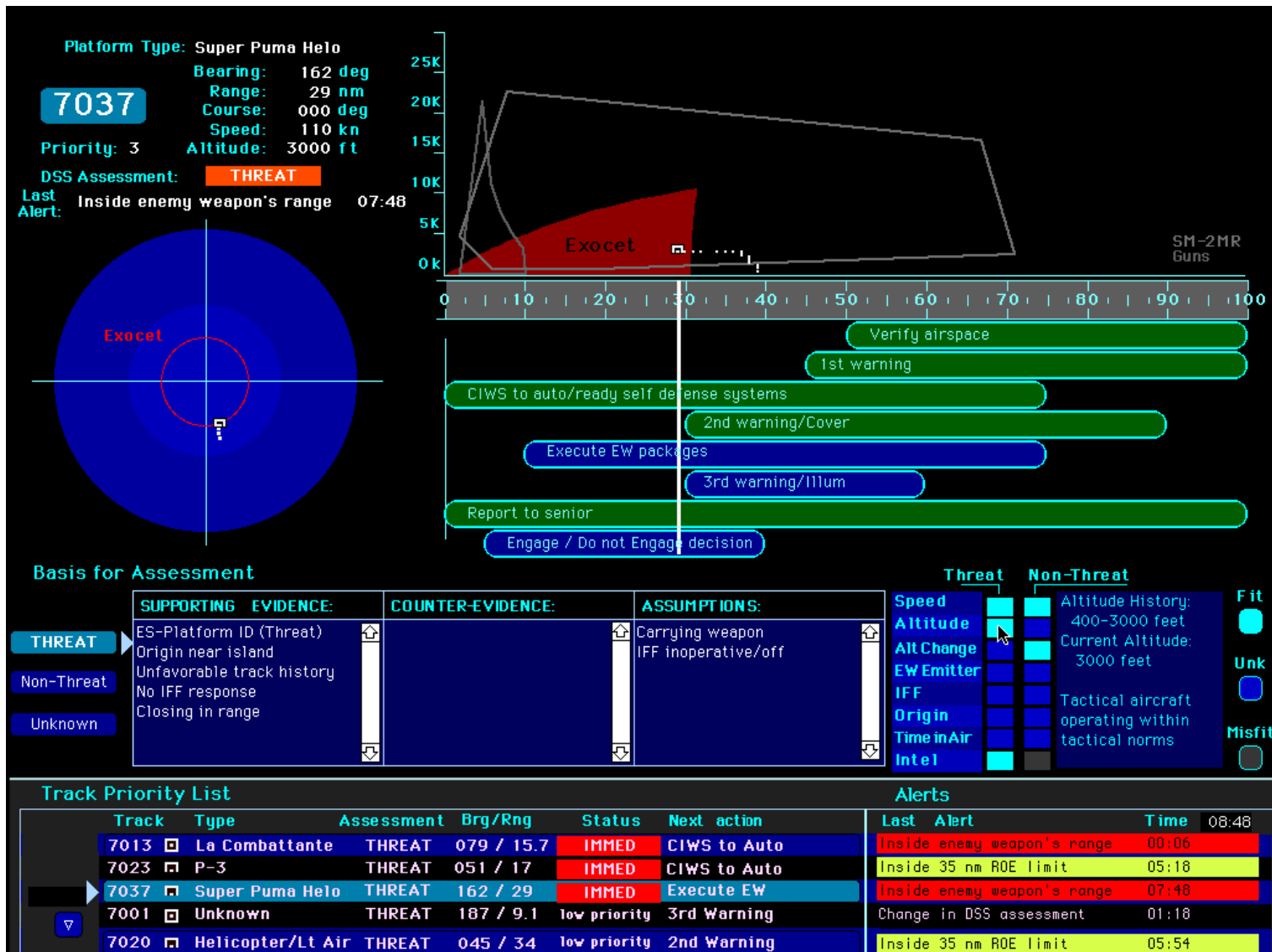
# Cognitive System Triad



Performance in complex, dynamic domains is the result of three interacting and mutually constraining components:

- Cognitive demands of domain of interest
- Cognitive resources of the decision maker
- Interface as a representation of the task and to mitigate demand/resource mismatches

# Overall DSS



# Track Summary



**Platform Type:** F-1

**7003**

**Bearing:** 120 deg

**Range:** 37 nm

**Course:** 118 deg

**Speed:** 600 kn

**Altitude:** 5000 ft

**Priority** 1

:

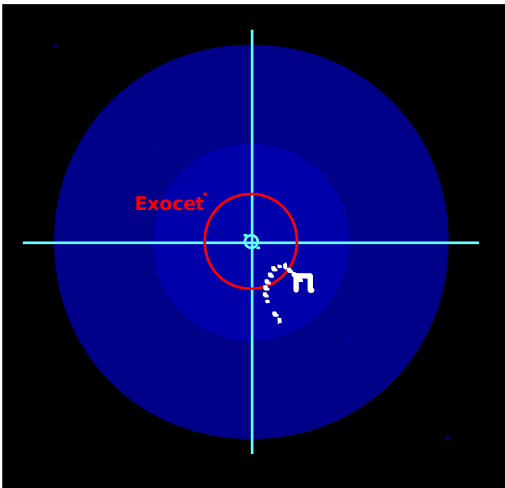
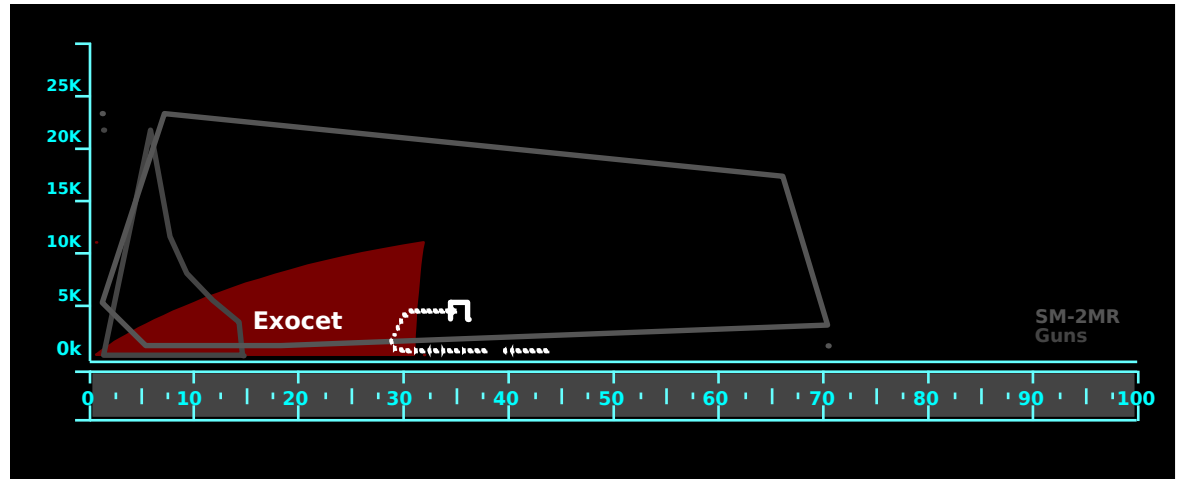
**DSS Assessment:** **THREAT**

**Last  
Alert:**

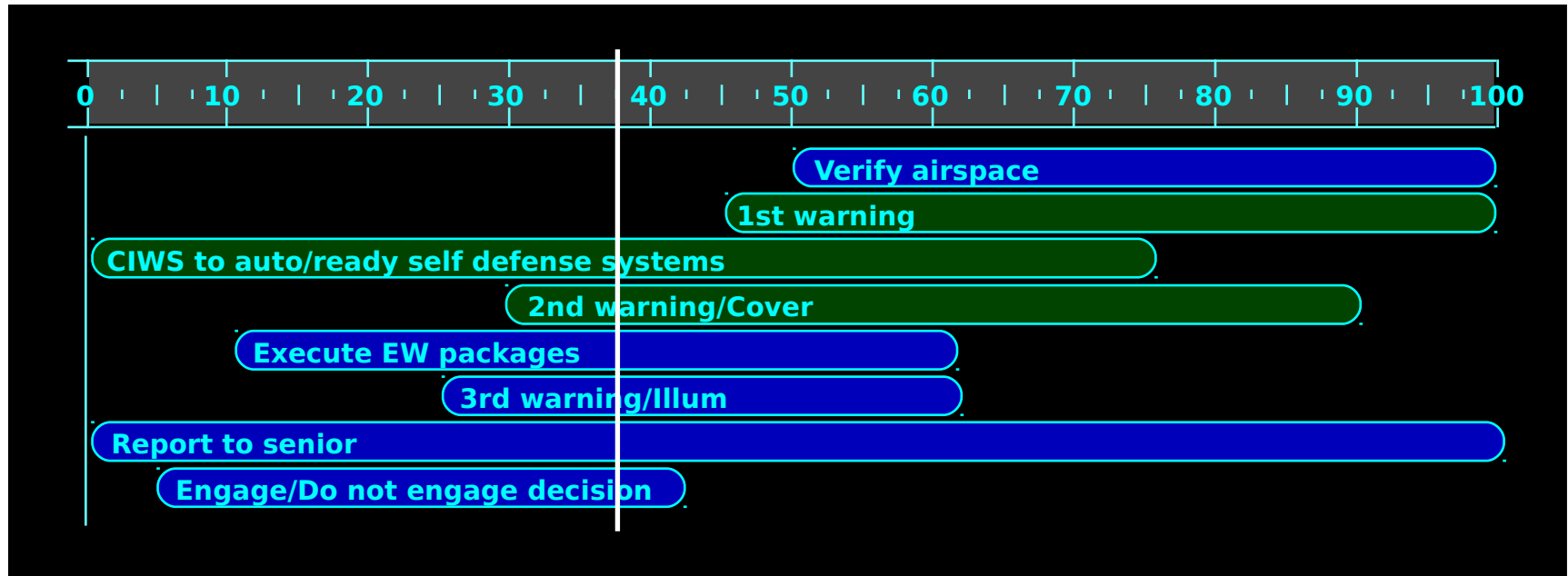
New track-low & fast

23:00

# Track Profile



# Response Manager



# Response Manager



Graphically presents ROE/Battle Orders/pre-planned response.

- What needs to be done now?
- What can wait?
- How long may action(s) be delayed?


Records/Displays actions taken for individual tracks.

- What has already been ordered/done?

Currently provides two generic response sets.

- Air threat track
- Surface threat track



# Status and Command Displays



- Status Displays—include the “why” information, informing user regarding what is known about current situation.
  - Increases accuracy of understanding system state.
  - Negates decision makers’ need to traverse the display processing stages in the reverse order (i.e., from a commanded response to a cognitive interpretation).
- Command Displays—tell user what to do without displaying reasons for command.

All modules designed to *support* the decision maker in performing requisite tasks without removing the DMr from decision making process.

# Basis for Assessment



## Basis for Assessment

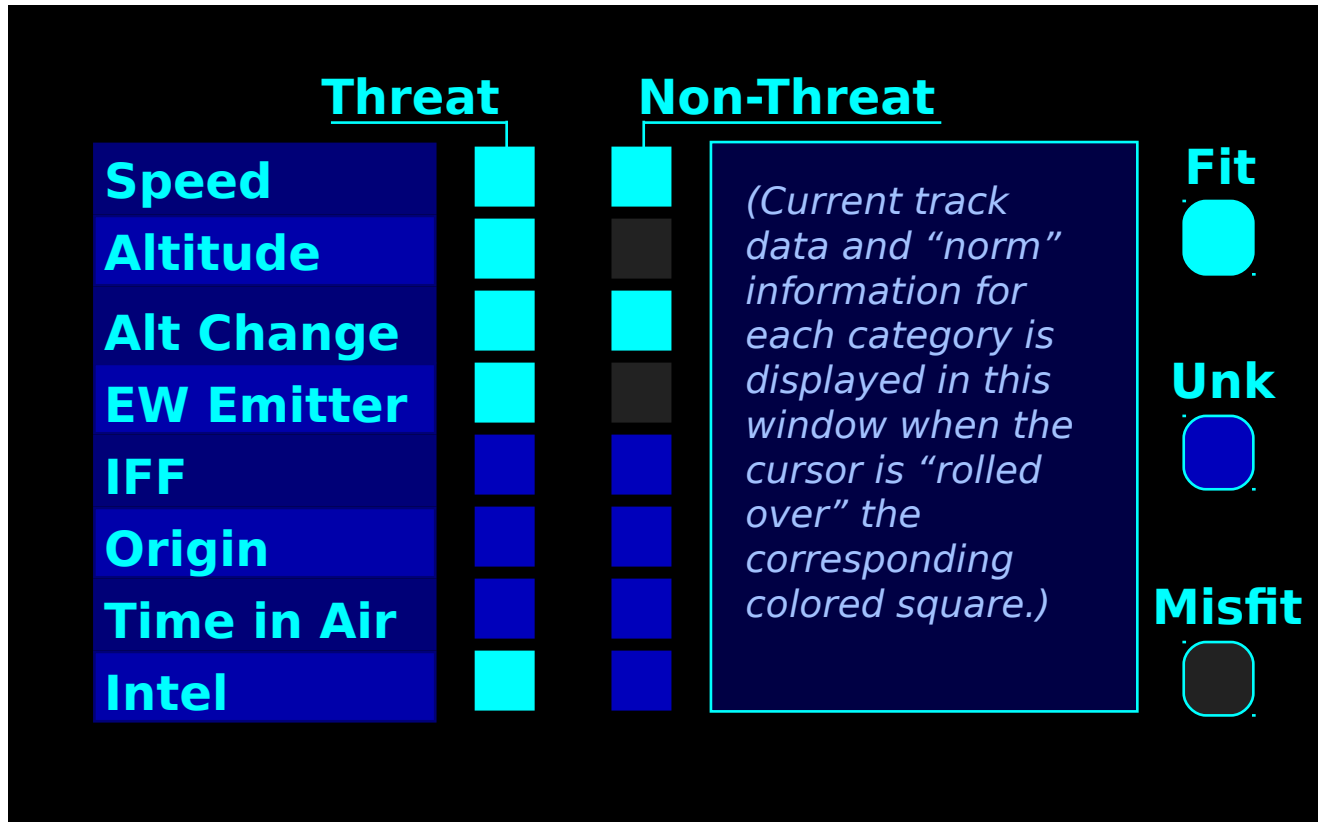
	SUPPORTING EVIDENCE:	COUNTER-EVIDENCE:	ASSUMPTIONS:
THREAT	ES-Platform ID (Threat)	Level flight	ES platform ID is reliable
	ASM capable platform	Outside weapons range	IFF inoperative/off
Non-Threat	Other units in company	Opening in range	Carrying weapon
	Unfavorable kinematics		Harassing ownship
Unknown	Unfavorable track history		Units acting in unison
	No IFF		Intel info is reliable

# Basis for Assessment



- Provides overall assessment of track—  
Support Explanation-based reasoning  
by showing how data supports  
alternative hypotheses.
  - Threat / Non-threat / Unknown
- Presents supporting evidence, counter evidence, and  
assumptions with regard to specific track assessments.
- Provides ability to consider alternate/competing hypotheses.
  - Last chance considerations before engagement decision


# Comparison to Norms



# Track Priority Lists & Alerts



## Track Priority Listing

7 of 10 ▲ ▼	Track	Type	Assessment	Brg/Rng	Status	Next action
	7020	F-1	THREAT	072/38	IMMED	3rd warn/Illum
	7040	F-1	THREAT	073/38	IMMED	3rd warn/Illum
	7003	F-1	THREAT	120/40	IMMED	Engage/Do not engage
	7007	Unk	THREAT	295/5	Watch	Execute EW packages
	7013	La Combattante	THREAT	075/12	Watch	Report to senior

## Alerts

Last Alert	Time
New air track-low & fast	26:03
New air track-low & fast	23:00
Radical change in kinematics	23:00
Radical change in kinematics	19:36
Radical change in kinematics	21:42
Inside 15 nm ROE limit	11:12

# Track Priority Lists & Alerts



- Track Priority Listing and Alerts:  
Summarizes key information about all tracks in order of tactical priority
- Prioritizes contacts of interest:  
What is the next potential threat?  
Summarizes key information about all tracks in order of tactical priority
- Provides an overview of high priority tracks:  
Where do we stand on these tracks? Are there any status changes?
- Prompts consideration of action:  
Should we warn/illuminate? Should defense action be taken?
- Promotes situation awareness
  - Directs attention to contacts/critical contacts of interest
  - Enables monitoring of multiple/concurrent tracks


# Advantages of Graphic Presentations



- Reduce the amount of mental computation required to perform tasks
  - Allow users to substitute less demanding perceptual operations for more complex logical operations
- Allow users to spend less time searching for needed information
  - Allow users to omit steps that are otherwise necessary when task is performed without a graphic
  - When several related dimensions of information are encoded in a single graphical object

# DSS Evaluation



- 4 Test Scenarios: 2 with DSS; 2 w/o DSS
- Data Collected:
  - Tactical Actions Taken
  - Voice Communications
  - Display Usage
  - Subjective Assessments
- DSS Promote Greater Awareness of Tactical Situation? If so, they would:
  - Ask fewer questions about previously reported track data and about the relative location of tracks;
  - Identify critical tracks earlier and more accurately;
  - Take more of tactical actions required by ROE and in a timely manner;
  - Have greater confidence in their picture of the tactical situation.



# DSS-1 Evaluation Study

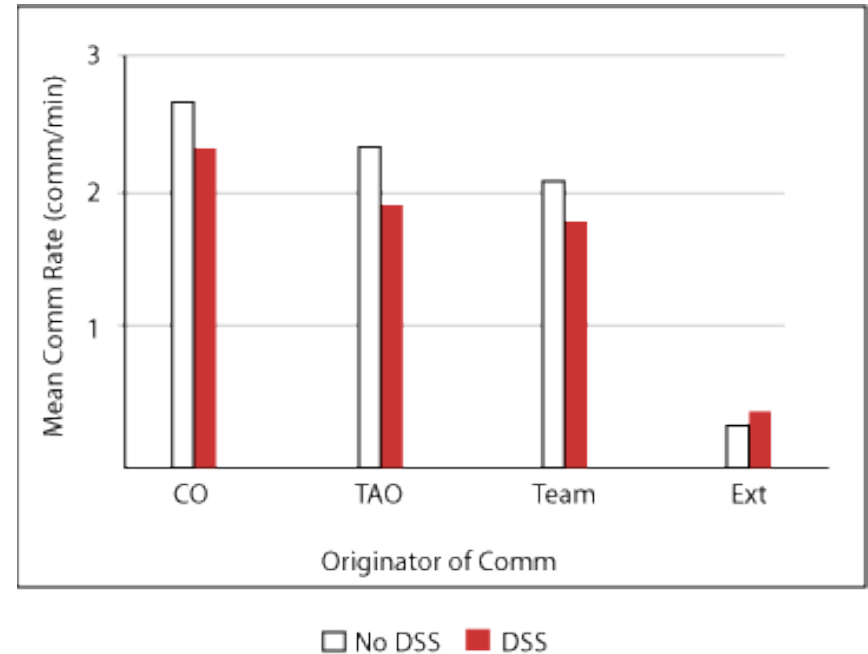


- Validate Utility of DSS-1
  - Qualified CO/TAO Teams
  - Utilize realistic littoral scenarios—Peace Keeping Missions
  - Compare performance with and without DSS
- Consistent Findings on DSS Use:
  - CO and TAO both used DSS.
  - Upper half used more often and considered more useful
  - Difference between how CO and TAO used the DSS, particularly the lower half.

# Does the rate of communications change when using DSS?



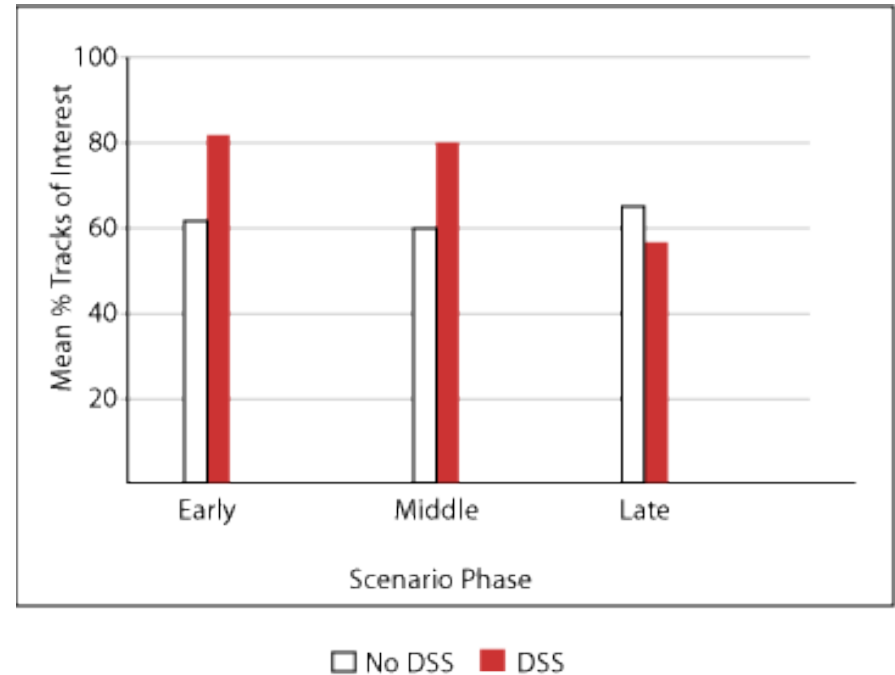
- Significantly fewer communications/minute overall with DSS (7.3 vs. 6.3)
  - Less need to exchange or verify data verbally
- Consistent effect for all originators of messages.



# Do teams recognize more critical contacts when using DSS?



- More tracks of interest were reported at early and at middle probes. *Subjects attributed to Track Profile.*
- No difference at late.
  - End-game more obvious.
- Most felt a positive effect of DSS (5.78 of 7 points)



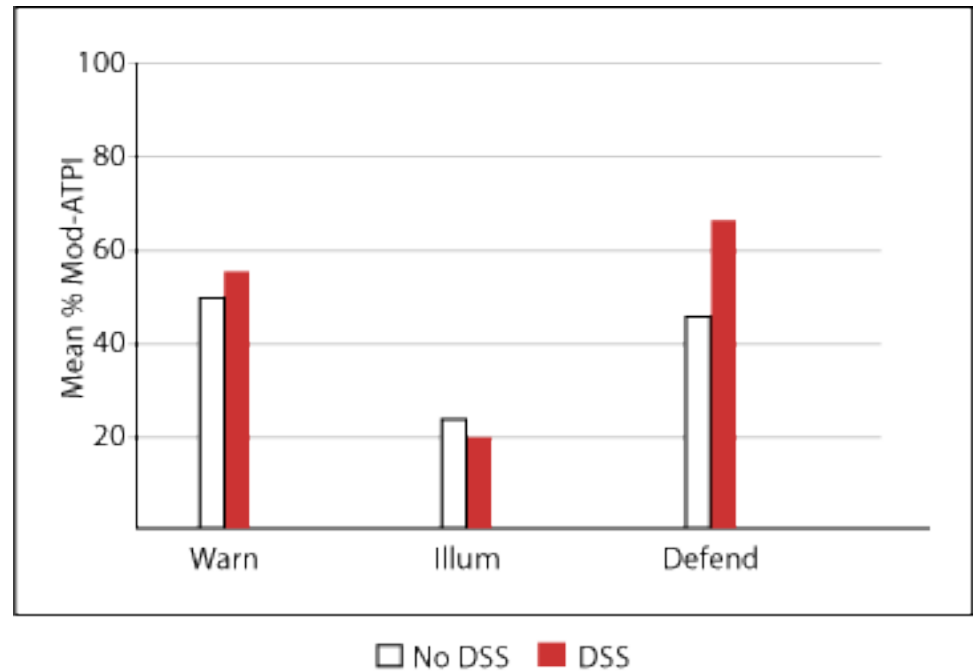
*"More confident of my grasp of the overall tactical picture and priority threats."*

# Do teams take more of the required actions against threat tracks with DSS?



Premise: Improved SA reflected by taking less-provocative actions earlier and more provocative actions later for a given track.

- Significantly more likely to take timely defensive measures.
  - Track Profile
  - Response Manager
- No difference in warnings and illuminations (provocative actions).



# DSS-1 Study—Conclusions



- CO and TAO use the DSS frequently.
- DSS is considered useful and adds value.
- Fewer communications and fewer of certain types of clarifications with DSS.
- More of the critical contacts recognized earlier.
- More likely to take defensive measures.
- DSS is easy to understand and easy to use.
- Many valuable suggestions for revising DSS.

# Differences between Current Systems and the TADMUS Decision Support System



	Current Systems	TADMUS DSS
Cognitive workload	Levy a high cognitive workload on the decision-maker that exceeds the limitations of human memory	Uses graphics to support intuitive processes and reduce cognitive processing requirements
Data organization	Do not present integrated data (i.e., information) to facilitate rapid decisionmaking	Presents data organized in some form
Evidence explanation	Do not assist in explaining available evidence	Threat Assessment constructs a set of explanations for the available evidence
Reminders	Do not assist in reminding decisionmakers of ROE and responses	Prompts decisionmaker regarding ROE and required responses
Comparison	Do not provide a tool to compare multiple hypotheses	Provides the ability to compare multiple hypotheses
Parallelism	Do not attempt to parallel the decisionmaker's cognitive strategies	Structures and presents information in a format that parallels the decisionmaker's cognitive strategies

# Decision Support System (DSS-2)



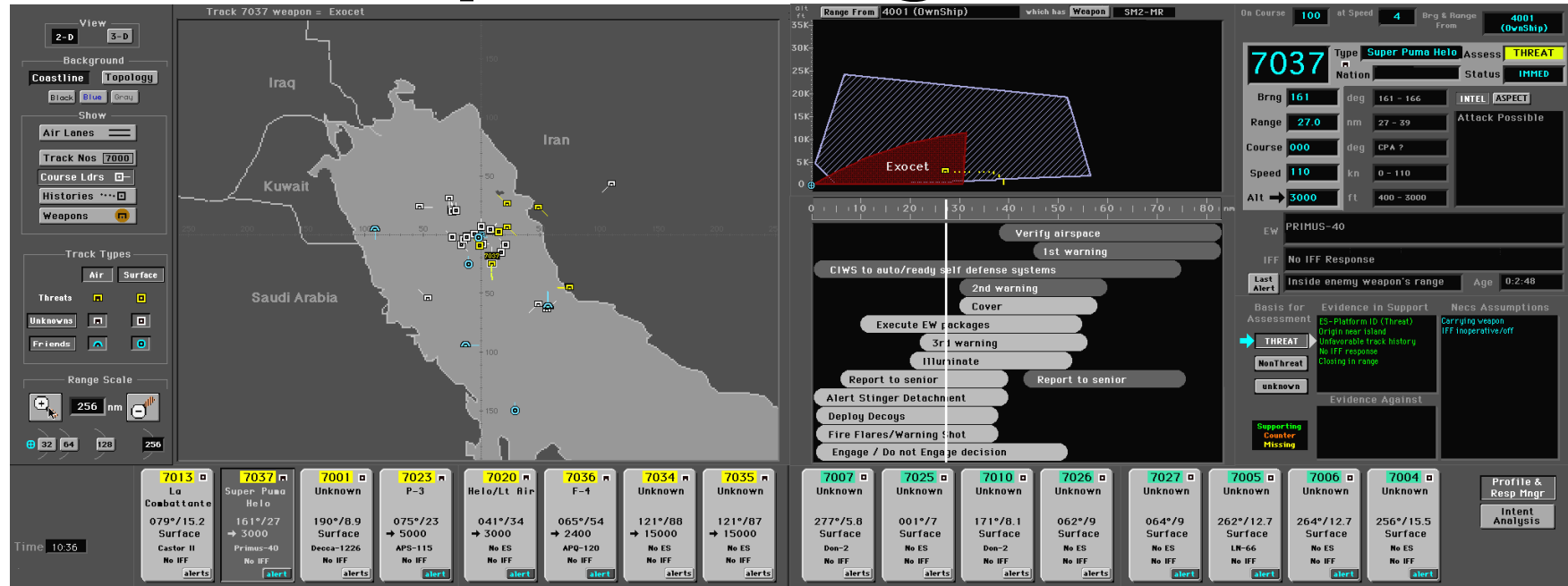
- Revised displays concepts based on the results from ongoing research with DSS-1.
- Integrates Geo-plot from existing CIC into the DSS.
- Incorporates new concepts derived from emerging cognitive theories/models and needs expressed by Fleet operators.
- Currently storyboard-operational in Summer, 1996.
- To be evaluated in simulations with revised scenarios.



# **TADMUS DSS-2**



# TADMUS DSS-2: CIC Conceptual Design



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Track 7037 weapon = Exocet

View

2-D

3-D

Background

Coastline

Topology

Black

Blue

Gray

Show

Air Lanes

Track Nos

7000

Course Ldrs

Histories

Weapons

Track Types

Air

Surface

Threats

Unknowns

Friends

Range Scale



128 nm

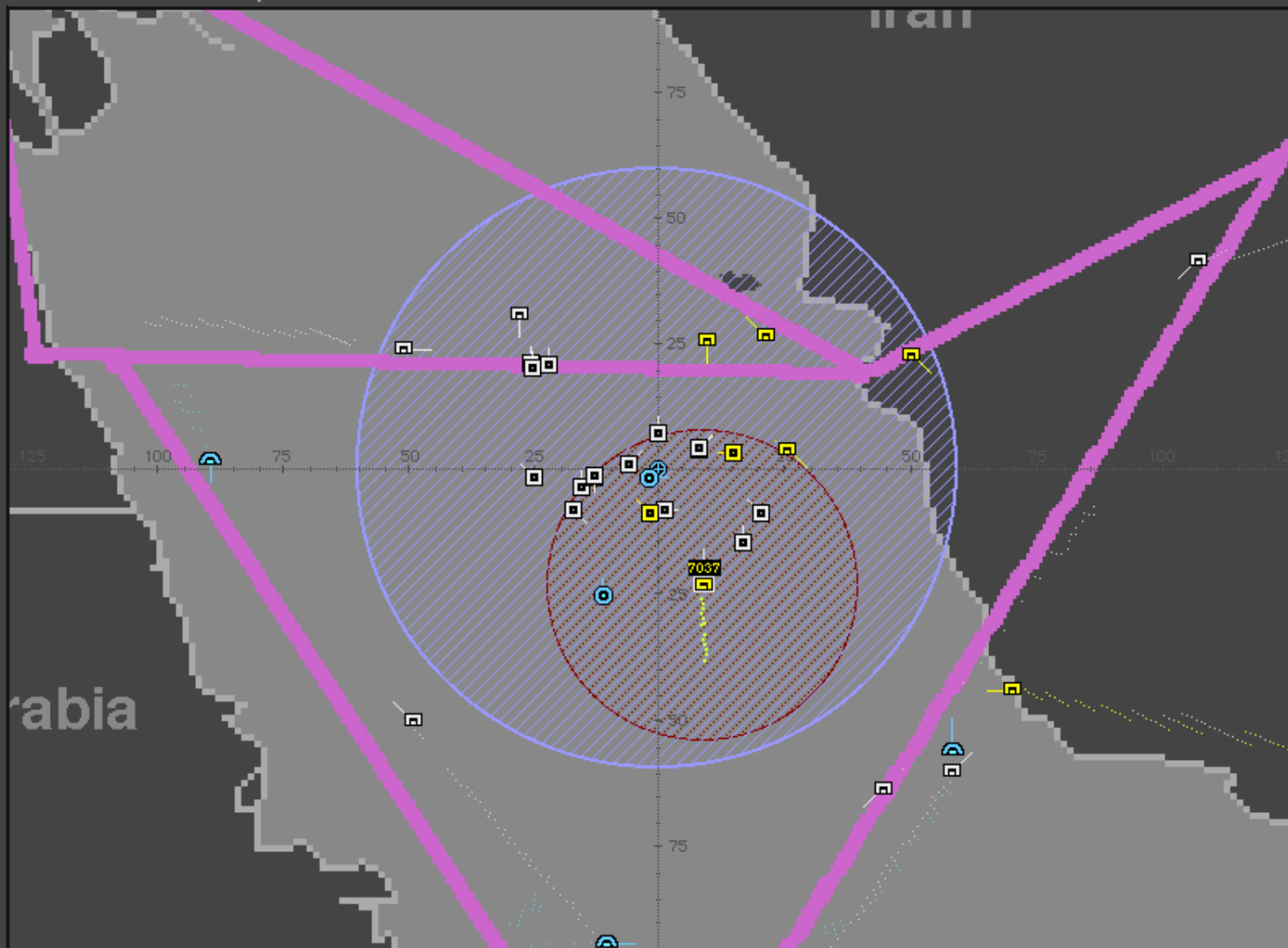


32

64

128

256



7013

La  
Combattante

078°/15.1  
Surface

Castor II  
No IFF

alerts

7037

Super Puma  
Helo

160°/25  
→ 3000

Primus-40  
No IFF

alert

7001

Unknown

190°/8.9  
Surface

Decca-1226  
No IFF

alerts

7023

P-3

081°/25  
→ 5000

APS-115  
No IFF

alert

7020

Helo/Lt Air

039°/34  
→ 3000

No ES  
No IFF

alert

7036

F-4

067°/55  
→ 2400

APQ-120  
No IFF

alert

7034

Unknown

122°/84  
→ 15000

No ES  
No IFF

alerts

7035

Unknown

122°/84  
→ 15000

Cyrano-IV  
No IFF

alerts

Time 11:18

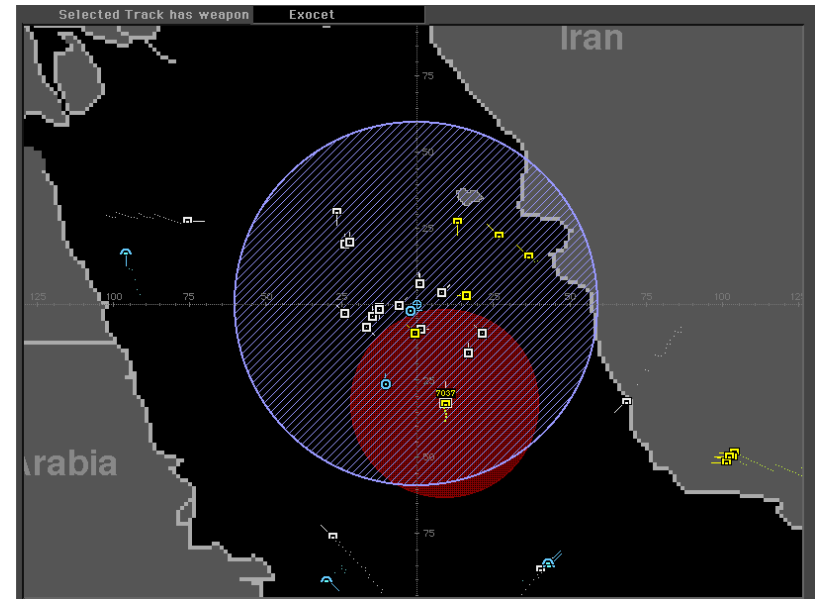
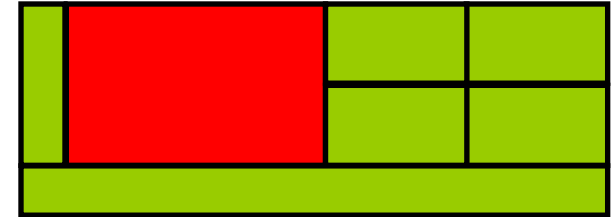
# Geo-Plot Display



**Symbology** shows all tracks in area - user can select tracks directly by touch. Track / button selection relies on AHA\*.

## Other Features:

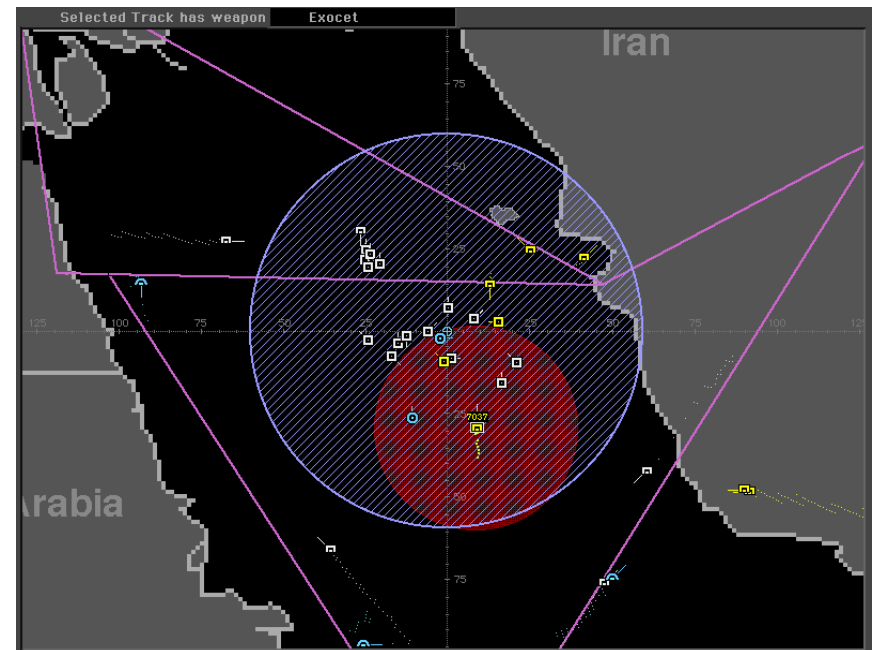
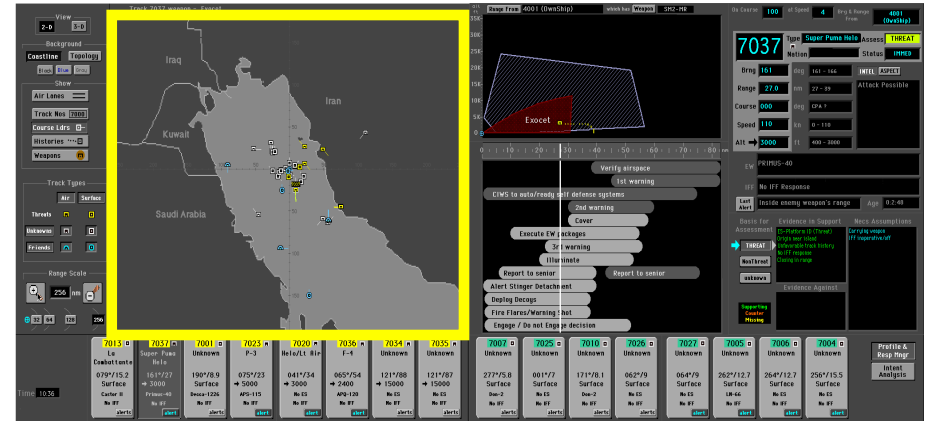
- Separate Map Layers below symbology can aid SA and assist in planning, e.g., Nav charts, topographic, meteorologic, population, power grids, transportation maps, etc.
- Optional geo-plot overlays for: SSM (with threat envelope), cities, air corridors, shipping lanes, track numbers, etc.
- Selected track shows history & threat envelope.
- Infinite zoom & pan.



- \*De-saturated map and "Advanced Hooking Algorithm (AHA)" adopted from Glenn Osga's work.

# Geo-plot with desaturated map, variable coded symbology

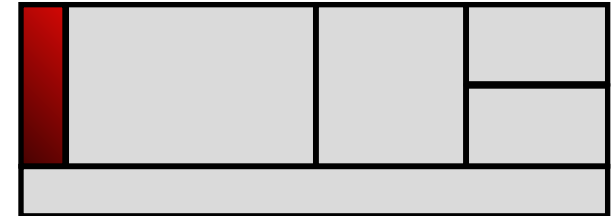
- Quick Decision making for SA.
- Variable-Coded NTDS Symbology (Osga et al.).
- Alternative map layers to support EBR in relevant context. (Desaturated map shown [Osga et al.] )
- Rapid scaling / declutter tools.
- Weapon envelopes for friendly & threat tracks.

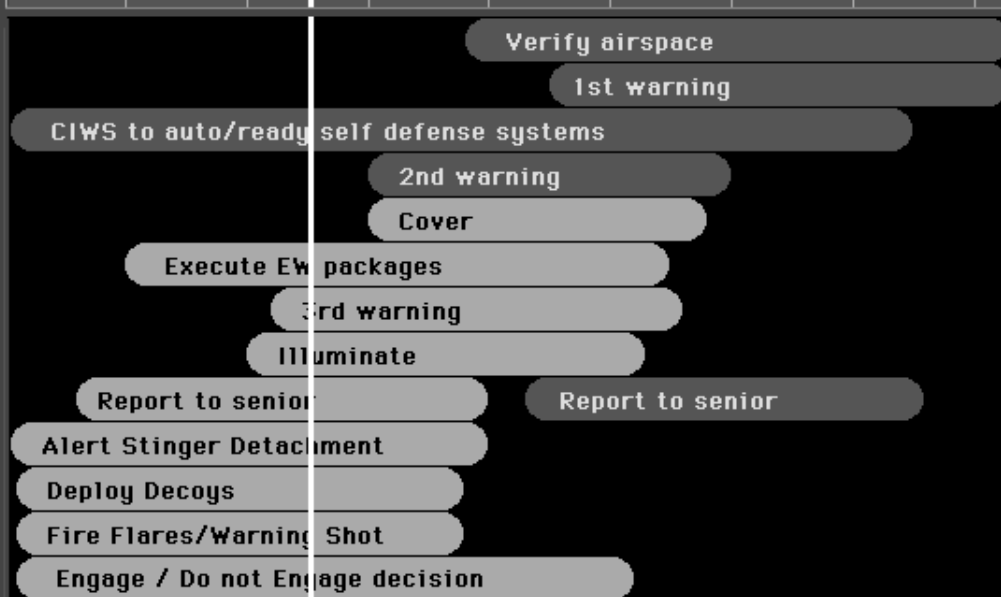
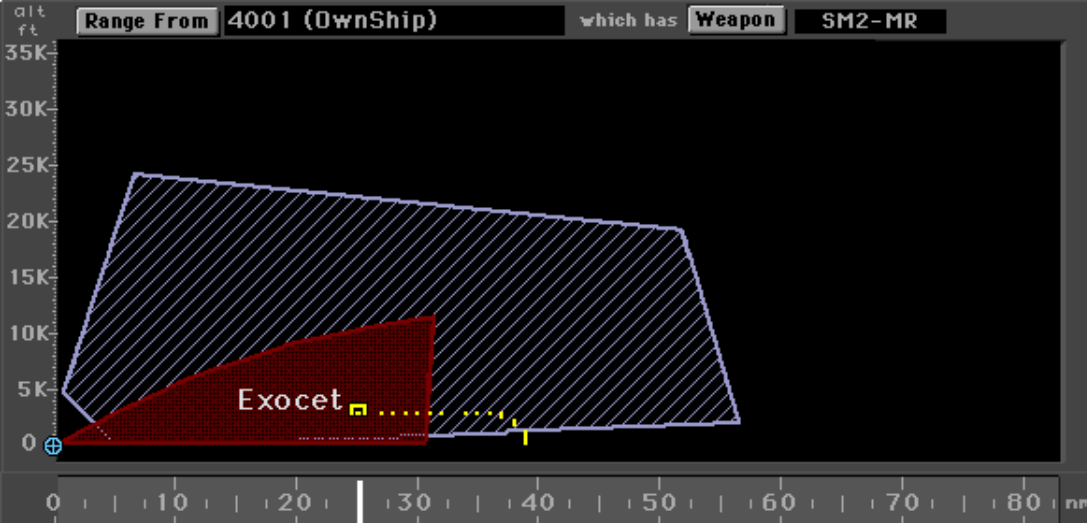


# Geo-Plot Control



- Touch-sensitive buttons, with click & hold or simple toggles to change appearance of Geo-Plot & maps.
- Some buttons are multi-state toggles, others on/off.
- Panel collocated with geo-plot for rapid and easy control of display, yet “out of the way” (outside central field of view).





On Course 100 at Speed 4 Brg & Range 4001 (OwnShip) From

7037 Type Super Puma Helo Assess THREAT

Nation Status IMMED

Brng 159 deg 159 - 166 INTEL ASPECT

Range 25.0 nm 25 - 39 Attack Possible

Course 000 deg CPA ?

Speed 110 kn 0 - 110

Alt 3000 ft 400 - 3000

EW PRIMUS-40

IFF No IFF Response

Last Alert Inside enemy weapon's range Age 0:3:48

Basis for Assessment

THREAT

NonThreat

unknown

Evidence in Support

ES-Platform ID (Threat)  
Origin near island  
Unfavorable track history  
No IFF response  
Closing in range

Evidence Against

Necs Assumptions

Carrying weapon  
IFF inoperative/off

Supporting Counter Missing

7035	7007	7025	7010	7026	7027	7006	7005
Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
122°/82 → 15000	279°/5.8 Surface	001°/7 Surface	171°/8.1 Surface	063°/9 Surface	064°/9 Surface	264°/12.7 Surface	262°/12.8 Surface
Cyrano-IV No IFF	Don-2 No IFF	No ES No IFF	Don-2 No IFF	No ES No IFF	No ES No IFF	No ES No IFF	LN-66 No IFF
alerts	alerts	alerts	alerts	alerts	alert	alert	alert

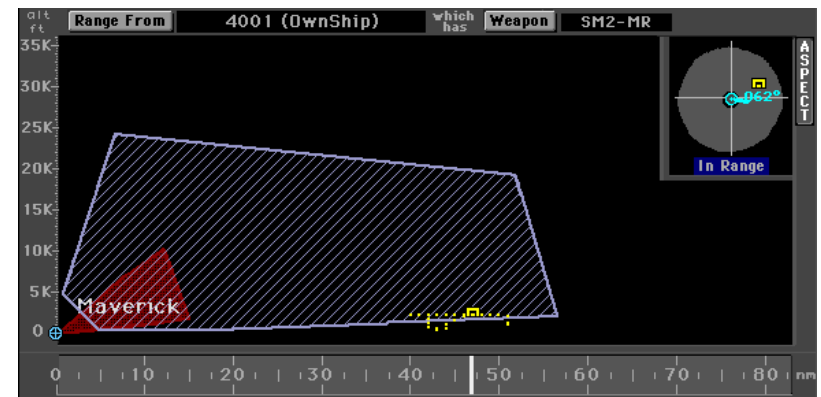
Profile &  
Resp Mng

Intent  
Analysis

# Track Profile



- Provides own ship and threat track weapon release overlays.
  - What weapon is carried by threat?
  - Could it launch against us?
  - Could we engage it?
- Displays the current position and track history for an individual track.
  - Altitude and range
  - Where is the track now?
  - What has the track been doing?
  - Is the threat increasing? decreasing?

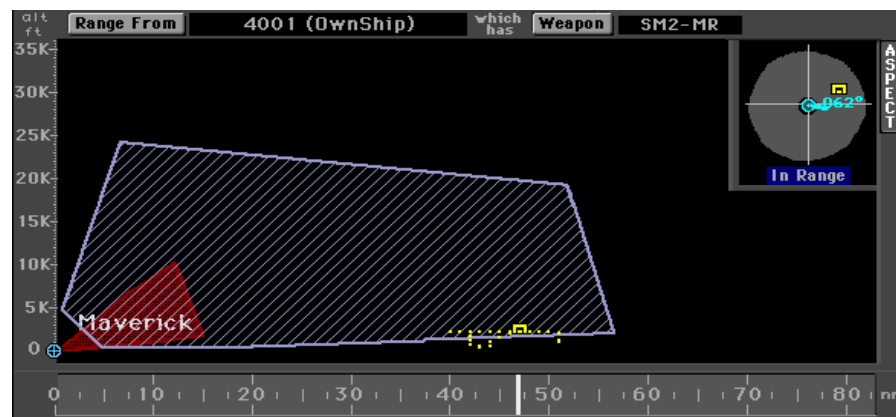
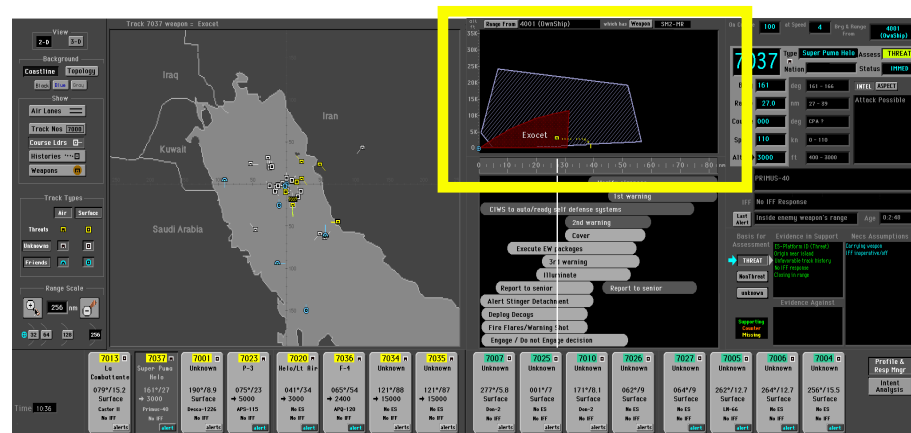




# Track Profile with Aspect Inset



- Supports RPD & Template matching.
- Shows altitude vs. range for selected track as well as weapon envelopes for friendly & hostile tracks.
- Rapid support for critical decisions:
  - Who is he? Where is he now? What has he been doing? Can he shoot me? Can I shoot him?
- Aspect shows relation to own ship course & speed. Supports:
  - Does he have minimal radar cross-section? Is he in weapon cut-outs?
- Drop-down buttons allow selection of alternative perspectives other friendly units & other defensive weapons.



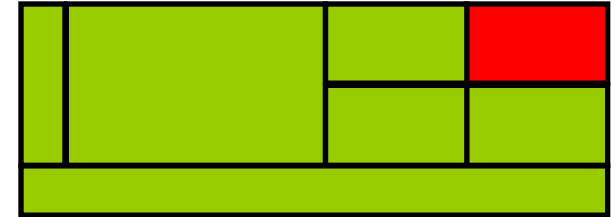


# Track Summary



## Features:

- Summary of current and historical data for a selected track.
- Useful as a “quick look” summary to clarify the status of a single track:
  - What is it?
  - Where is it?
  - What is the threat assessment?

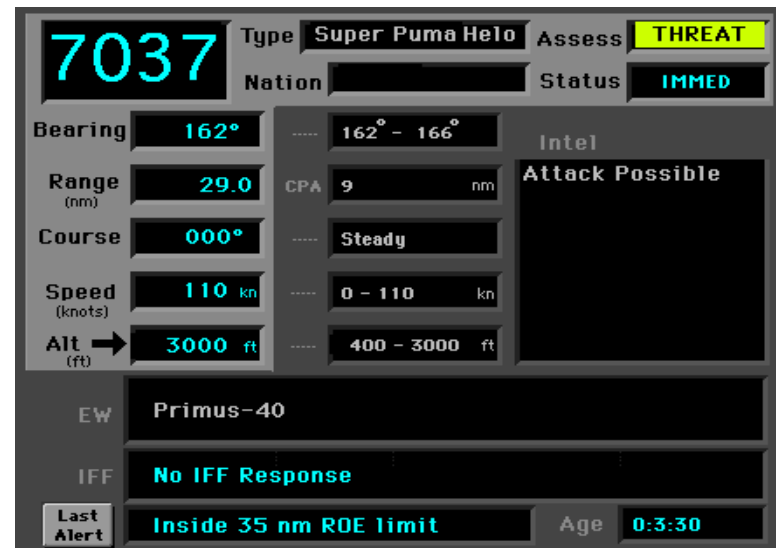
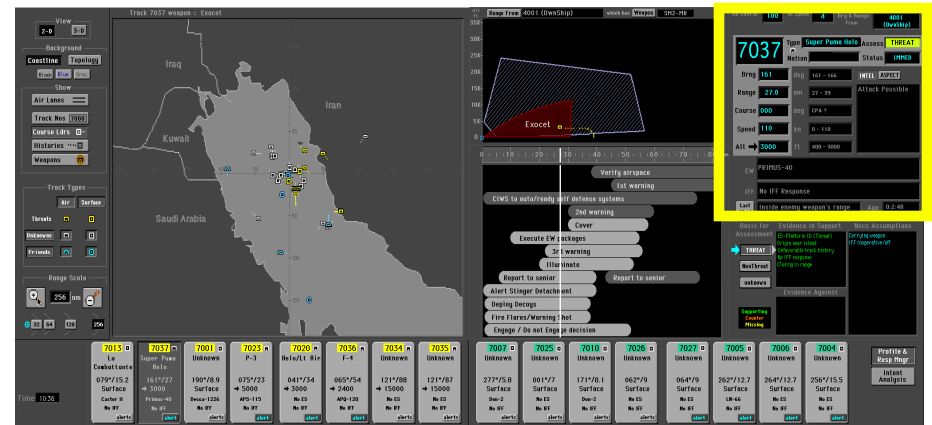


<b>7037</b>		Type	Super Puma Helo	Assess	<b>THREAT</b>
		Nation		Status	<b>IMMED</b>
Bearing	<b>162°</b>	162° - 166°		Intel	
Range (nm)	<b>29.0</b>	CPA	9 nm	Attack Possible	
Course	<b>000°</b>	Steady			
Speed (knots)	<b>110 kn</b>	0 - 110 kn			
Alt (ft)	<b>3000 ft</b>	400 - 3000 ft			
EW	Primus-40				
IFF	No IFF Response				
Last Alert	Inside 35 nm ROE limit			Age	<b>0:3:30</b>

# Track Summary



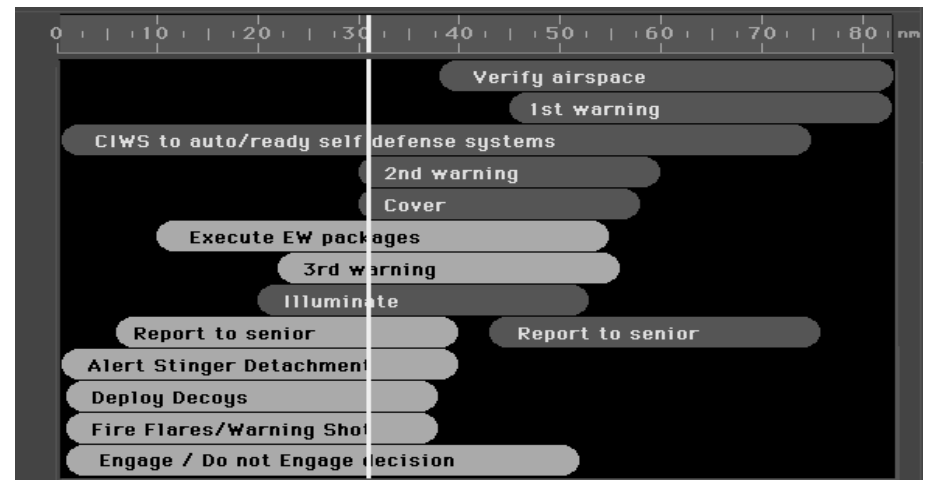
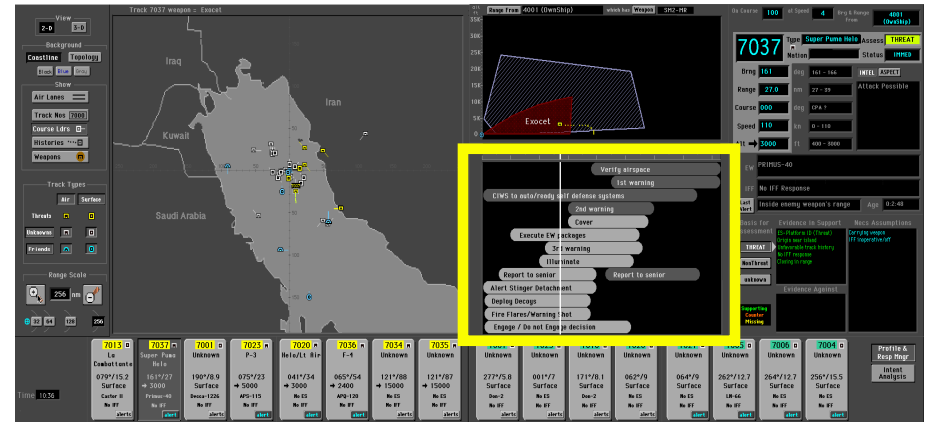
- Supports EBR & SA through detailed presentation of ID, kinematic & ancillary data.
- Current data shown in cyan, historical data in grey. Quantitative data arranged in tabular format, text left-to-right.
- Shows current intelligence, EW, IFF data and their implications for detailed analysis by the decision maker.



# Response Manager



- Supports EBR related to pre-planned responses & SA.
- Tied to Track profile by current range scale & present position line.
- Gantt chart type display encompassing ROE & battle orders.
- Serves as template for what was planned for a given track type.
- Shows what actions have been taken on a track by track basis.

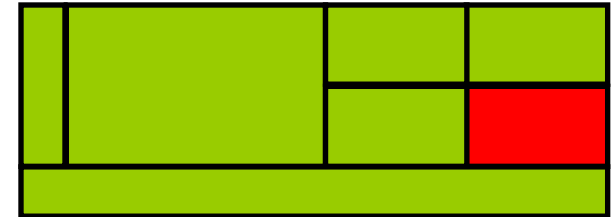


# Basis for Assessment



Provides overall assessment of track.

- Threat, Non-Threat, or Unknown
- Presents supporting, counter, inconclusive, and missing evidence for a selected assessment, and assumptions with regard to specific track assessments.



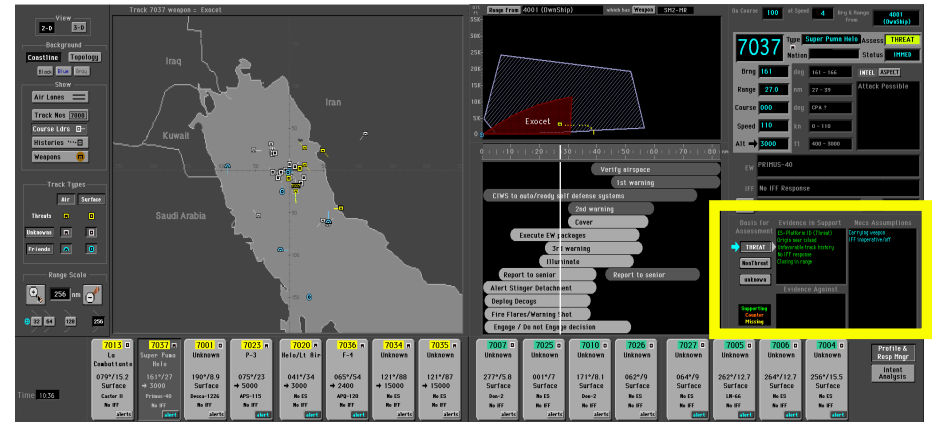
Basis for Assessment	Evidence in Support	Necs Assumptions
<b>THREAT</b>	ES-Platform ID (Threat) No IFF response Origin near air base Closing in range Origin in territory Intel-Attack possible	Conducting targeting Carrying weapon IFF inoperative/off
NonThreat		
unknown		
	<b>Evidence Against</b> Outside weapons range	

- Provides ability to consider alternate / competing hypotheses

# Basis for Assessment



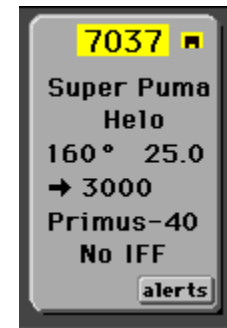
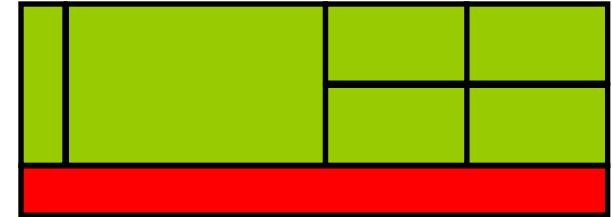
- Supports EBR by presenting all relevant data as supporting, against or missing with regard to three assessments : Threat, Non-threat, or Unknown.
- Presents necessary assumption in order to accept selected hypothesis.
- Uses rule-base logic to sort data.
- Allows decision maker to consider alternative hypotheses and seek out missing data.



# Multiple CROs



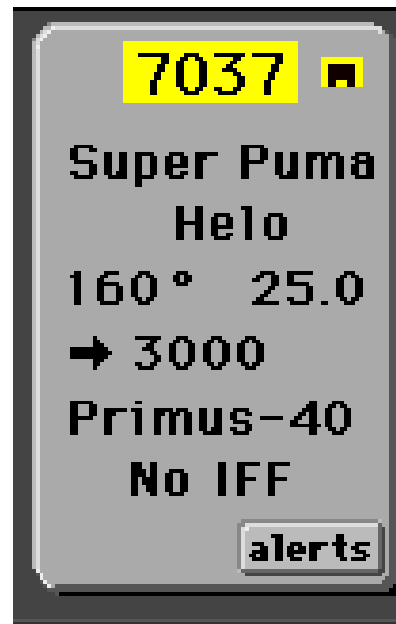
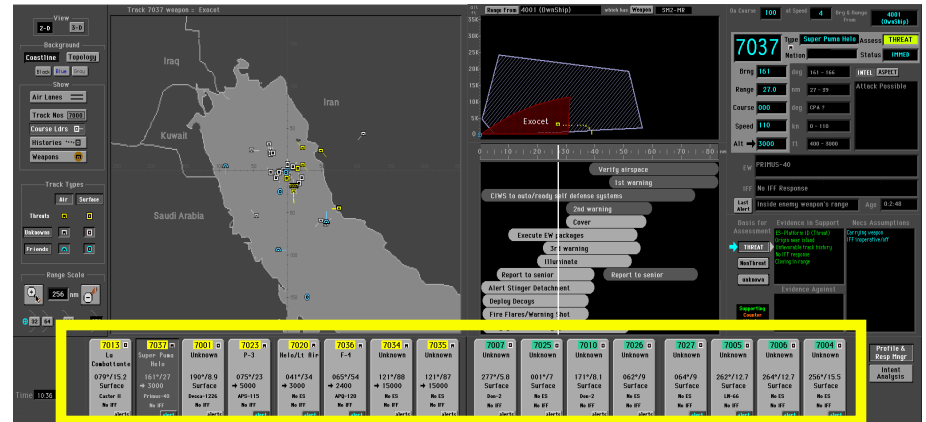
- Multi-CRO Access Panel
  - Provides direct access to, and ability to monitor the 16 highest priority tracks and displays tracks' "key" information.
- Facilitates multi-track management.
- Assists in attention allocation.
- Displays alert status, provides history of alerts for each track.



# Mini-Character Read Outs (CROs)



- Supports quick decision making for S.A. & R.P.D.
- Serves as quick-Access buttons to 16 highest priority tracks.
- Provides critical access to ID, kinematic & alert information on track by track basis. Elaborates on multi-dimensional coding of NTDS symbols.
- As situation evolves, Mini-CRO movement attracts attention.

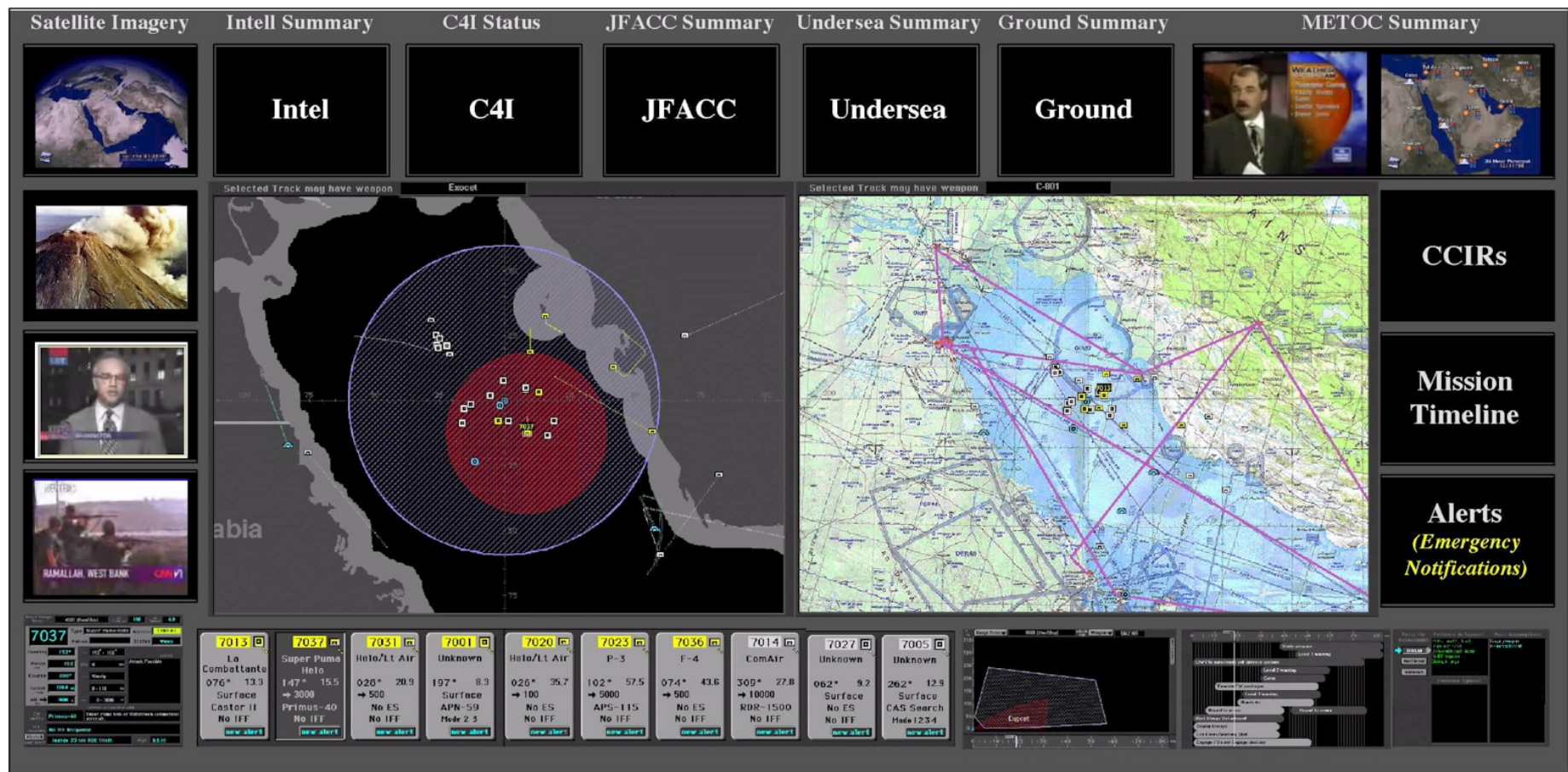




# The Command 21 “Knowledge Wall” vision



**Conceptual CJTF Collaborative “Knowledge Wall”:**  
A “Picture Window” into a “sea of information”  
displayed using a “data wall” & fed from Anchor Desk DSS’s.



“Enabling Knowledge-Centric Warfare for Fleet Decision-makers”



# Global 2000 - Prototype Knowledge Wall



To be  
installed  
at Naval  
War  
College &  
aboard  
USS  
Coronado.

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# Why a “Knowledge Wall”?



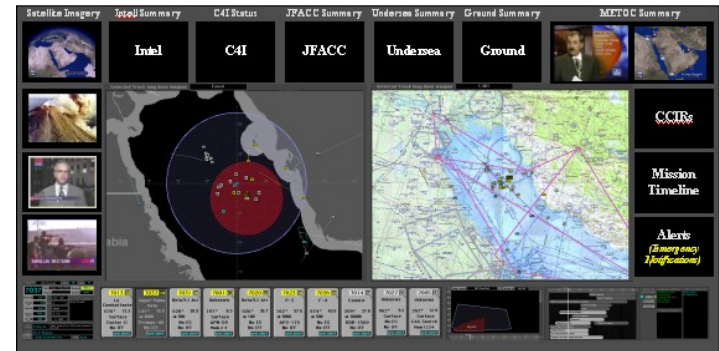
- Suggested by requirements identified through “Knowledge Engineering” with C3F & C2F command staff over past 3 years.
- Intended to *facilitate* knowledge for key JOC personnel through use of decision support & collaboration technology. Relies on “knowledge management” processes for content.
- Product of number of years of research
  - Decision-making & Effects of Stress
  - Decision Support Technology (e.g. TADMUS)
- Under accelerated development for Global 00 at request of C3F & CCG-1, with ONR sponsorship.

# Limiting Factor: Current Technology



## End Vision

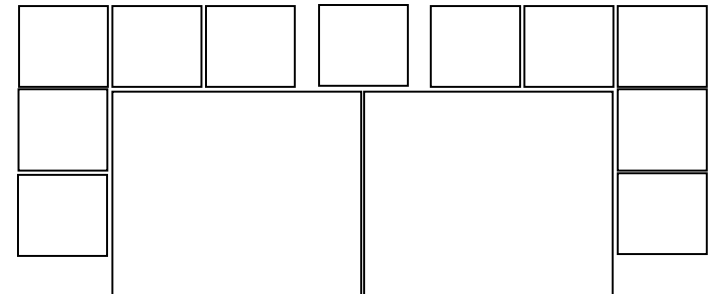
- A single, wall-sized, fully configurable display
  - Virtually unlimited number and sizes of windows in single “desktop”.
  - Dedicated Decision Support tools.



## State-of-the-art

- Multiple smaller displays arranged in a grid pattern
  - Number and size of windows limited due to hardware cost
  - Heavily reliant on “browser” technologies.
  - Resolution of windows limited due to software status
  - Single integrated “Desktop”.

← ~ 20' X 10' ? →



# Global 00 Functional Organization



Functional Area (CJTF)	Responsible Agent
Ground Control /CAS	ARFOR MARFOR
OMFTS	MARFOR
TMD	NAVFOR ARFOR
Air Defense	AFFOR
Deep Strike / Interdiction	AFFOR
Sea Control	NAVFOR
SOF	JSOTF
Rear Area Security	(Brown)
ISR	J2
Fires Coordination	J31
Effects	J35
Information Warfare	J39
Logistics	J4

# Cognitive Tasks Analysis Results: Common Information Requirements



- Tactical data (multiple views if possible!)
  - Map-based and highly graphical views / context
- Mission Summaries and Commander's Intent
- Real-time info! (*or close to it*)
- Alerts / Advisories / Recommendations
  - What isn't working according to plan?
  - What do we do to fix it?
- Impacts & Indications
  - "X" happened; how does it affect everything else?
- Plans (and alternate COAs)
  - Response & Timeline Management
- Effects Summaries
  - Various formats preferred
- Asset / Resource Management
- Collaboration Tools (*including VTC*)

# Basic Summary Display Layout



- Simple, consistent design for most KW summary pages
- Most of display is readable at ~15 feet
- Supports graphics, text, multimedia
- Features
  - Title / Summary
    - Color-coded indicators
  - Alerts & Advisories
  - Impacts & Implications
  - Related Links

## Domain / Title



[Current](#)



[Next 24 hrs](#)



[48+ hrs](#)

Graphic /  
Media

*Last Update (date / time)*

## Alerts

[HTML Link to WIGS page](#)

[HTML Link to WIGS page](#)

## Impacts

[HTML Link to WIGS page](#)

[HTML Link to WIGS page](#)

[HTML Link to WIGS page](#)

## Links

[HTML Link to WIGS page](#)

[HTML Link to WIGS page](#)

- ♦ Can be accessed directly from summary display or shifted to one of the focus windows





C:\KWS\Shared\Overview\Overview1.htm - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites History

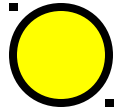
# Overview1

Last Update 08/16/00 06:20 a

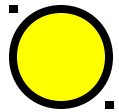
- Gnd Ctrl-CAS
- OMFTS
- Sea Control
- TMD
- Air Defense
- Deep Strike
- SOF
- Rear Security
- ISR
- Fire Coord
- Effects
- Info Warfare
- Logistics

# METOC

Last Update 31 May, 2000 09:42



[\*Today\*](#)



[\*Tomorrow\*](#)



[\*Long  
Range\*](#)



## Alerts

[\*Tropical storm  
approaching  
High surf advisory\*](#)

## Impacts

[\*Small craft are  
endangered  
Air Ops may be affected\*](#)

[\*Photo sat coverage  
impaired\*](#)

## Links

[www.metoc.com](http://www.metoc.com)

[www.weather.com](http://www.weather.com)



# Notional Layout



VTC or News broadcast  
(not part of KW, exact size TBD)



145.4 inches (~12 feet) across

# Global 00 - Lessons Learned: Summary



- Improved integration of KW and other IT tools is necessary
  - Reliance on “manual” integration of information is manpower intensive
  - From user perspective, multiple HCIs present problems
- Method with which KW information is distributed / hosted must be redressed and optimized
- Connectivity issues should be resolved in the future to limit their impact on KW ConOps. Must address *bandwidth management* for distributed users.
- Archival and access of KW information should be accommodated (for many reasons)
- KW support tools (Summary Maker and TacGraph) should be improved to better support users needs

# Global 00 - Lessons Learned: Summary (Cont.)



- “Knowledge Warrior” vice “Knowledge Manager”
- Global 2000 highlighted need for business rules re: information exchange.
  - Advisories & Alerts
  - Cultural issues in Joint & Coalition environment
- Tools needed to reach across echelon - accommodate “distant” users of content, e.g. CJTF Summary for CINC.
- Role of VTC unclear.
- Clearly need larger desktops for content producers & key decision-makers.
- Common Operating Picture does *not* mean a single picture - but common databases!
- KW may be too big & encompassing - may want to revise CONOP.
- Demonstrated that IT & collaboration technologies can dramatically increase “Speed of Command”
  - TacGraph needs to be deployed a.s.a.p.
  - KW & JOC of the Future CONOP substantially validated.

# Conclusion



## TADMUS

Decision support concepts for *tactical* decision makers which are:

***Theoretically derived,  
Empirically tested,  
Fleet Validated.***

# Conclusion



## Command 21:

Enabling *Knowledge-Centric Warfare*  
for Fleet decision makers

***Based on world-class science  
Empirically tested,  
Fleet Validated.***



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**(619) 553-9070**

# Conclusion



## Global 2000 Knowledge Wall:

Exploring the implications of Network-Centric Warfare on the *Speed of Command*

***Based on world-class science  
Empirically tested,  
Fleet Validated.***



Pacific Science  
& Engineering

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**SPAWAR**



*Systems Center  
San Diego*

**Jeffrey Morrison, Ph.D.**  
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**(619) 553-9070**

# TADMUS DSS Studies



## *Are we on the right track with DSS?*

- Objectives
  - Determine overall effects of DSS
  - Examine the use of DSS modules
- Method
  - Scenario-based Testing
  - Littoral, Peace-keeping, Air & Surface Warfare
- Research Questions
  - Situation Awareness
  - Communications
  - DSS Utility
  - DSS Usability

# DSS Studies—Conclusions



- CO and TAO use the DSS frequently.
- DSS is considered useful and adds value.
- Fewer communications and fewer of certain types of clarifications with DSS.
- More of the critical contacts recognized earlier.
- DSS improved track identification significantly - without affecting policy (bias).
- More likely to take defensive measures.
- DSS is easy to understand and use.
- *We know how to build operationally effective decision support!*



# TADMUS Lessons Learned: Key Decision Support Objectives



***Recognize cognitive capabilities & limitations, effects of stress, and DO NOT take decision-making away from decision-makers!***

- Facilitate Attention Management
  - Maintain general situation awareness
  - Avoid fixation on single events, tasks, or deadlines
- Provide Memory Aids
  - Provide stable locations for information
  - Avoid requiring recall & translation of specific facts & figures
  - Support recall of current state of interrupted procedures
  - Support historical context, highlight trend information
- Enable Pattern Recognition
  - Support incremental action/decisions, tailoring & scaling of actions
  - Assemble related information into a unitary picture
  - Provide information re: relations among objects/events to support explanation-based reasoning

# What the Global KW is ...



- A prototype (v. 1.0) & research tool using beta software and untested concepts.
  - Really a *data wall* with a concept of operations & collection of decision support tools.
- Part of a larger concept of operations for how to manage knowledge in a military command center. Concepts are not easily separable!
- An attempt to explore how emerging technology *should* be used to take advantage of network-centric warfare to enable knowledge-centric warfare at CJTF echelon.
- An evolving concept that will change based on continued Fleet input.

# Candidate KW Information from CTAs



## Functionally organized:

- Space
- Airz
- Land
- Sea
  - Sea control
  - Submarines
  - Mines
- Coalition
- TAMD
- Strike
- Fire Coordination
- Effects Based Ops

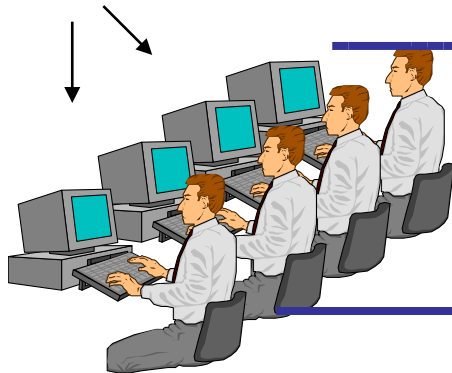
## Organizationally organized:

- Intell – J2
- Current Ops – J3
- Logistics – J4
- Future Ops / Plans – J5
- C4I Systems / KM – J6
- METOC
- ROE / JAG
- SOF
- Component Commanders

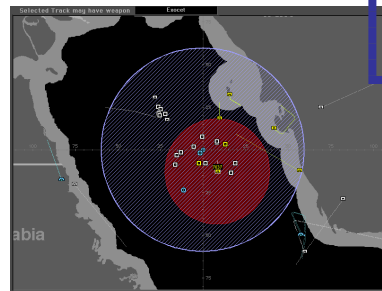
# Revised System Setup



**Anchor Desks  
(J2, J3, etc.)**



**Tactical Picture(s)**



**Intranet** →

**Other Info**

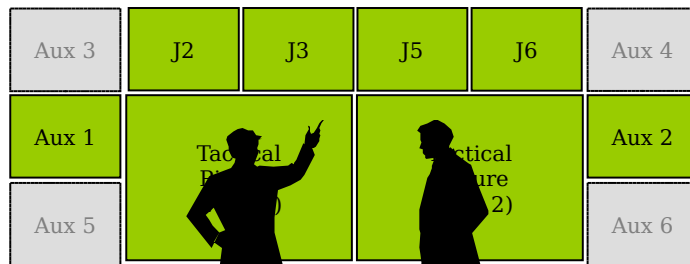


**Server(s)**

**KW PC**

**Cordless Pointing  
Device (TBD)**

**Projected Images or LCD Panels**



# Domain / Title

*Last Update (date / time)*

 ***Current***

 ***Next 24***

 ***hrs***  
***48+ hrs***

Graphic / Media  
(map, video,  
picture, etc.)

## Alerts

[HTML link to WIGS / local page](#)

[HTML link to WIGS / local page](#)

## Impacts

[HTML link to WIGS / local page](#)

[HTML link to WIGS / local page](#)

[HTML link to WIGS / local page](#)

## Links

[HTML link to WIGS / local page](#)

[HTML link to WIGS / local page](#)

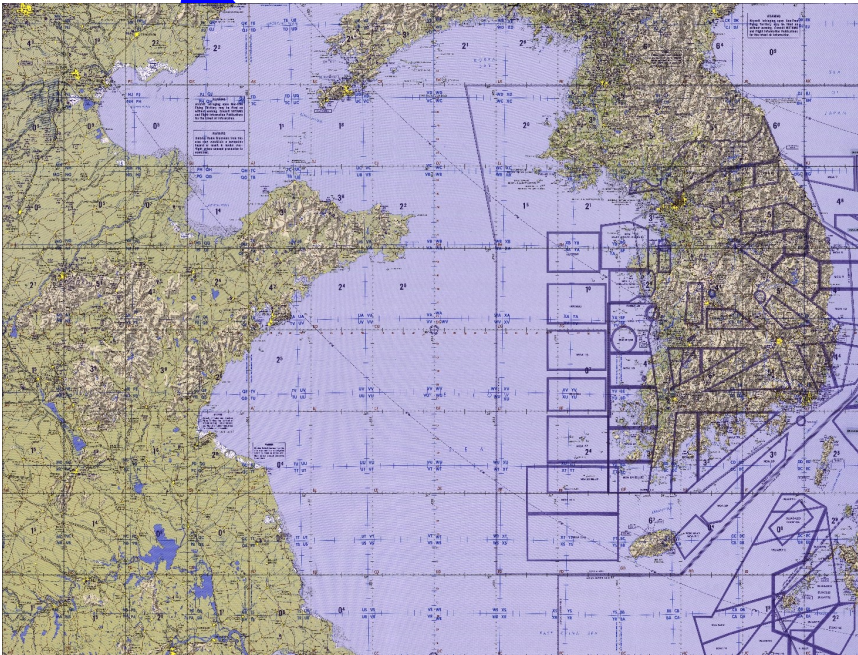
# Land

Last Update 31 May, 2000 09:42

● *Today*

● *Tomorrow*

● *Long*



## Alerts

*Unscheduled troop movement*

## Impacts

*Plan timeline now inaccurate*  
*Own force units not in position*  
*Coalition East flank vulnerable*

## Links

*[www.intel.mil](http://www.intel.mil)*

*[www.coalition.au](http://www.coalition.au)*